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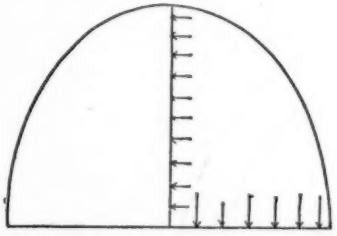
THEORY OF ARCHES.

(*Continued from page 296.*)

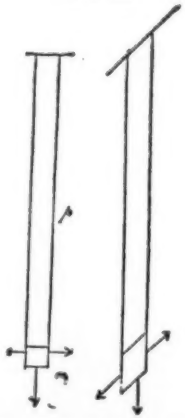
4. There is no case in ordinary practice where the pressures upon an arch are strictly identical with those on an elliptical cord, for in this case, the pressure must be constant in intensity along both the horizontal and vertical projections of the arch, but the intensity along the *horizontal* must differ from that along the vertical in a constant ratio (Fig. 41). But as Prof. Rankine says, the curve of equilibrium for the arch of a tunnel through earth, when the depth below the surface is great compared with the rise of the arch itself, approximates to an ellipse.

Fig. 41.



The pressures in a mass of earth are intermediate in character between those existing in a solid and those in a liquid mass. Thus a little cube of earth (Fig. 42) under the weight of the superincumbent column of earth p, presses downward with a force equal to its own weight and that of the column above. It also presses out horizontally with a force *less than this downward force*, but always *bearing a constant ratio to it*. If the little cube were *solid* it would have *no* horizontal push; if *liquid*, that horizontal push would equal its pressure downward. If the upper surface of the earth is inclined, the outward push which always remains parallel to it becomes inclined too, and is then "conjugate" to the vertical.

Fig. 42.

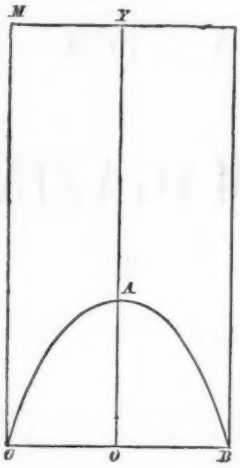


If M Y (Fig. 43) is the surface of the earth, when Y A is great compared with A O, then Y A and M C differ so slightly that we may assume them to be equal. We then have on the arch a uniform vertical load whose intensity =

$p_v = (\text{Y A}) \times$ weight of a unit of the earth $= wy_0$;

and a horizontal load whose uniform intensity p_x is equal to the vertical intensity (p_y)

FIG. 43.



multiplied by a constant. Let

$$\frac{p_x}{p_y} = c^2 \text{ (a constant).}$$

Then

$$p_x = c^2 w y_0 \text{ and } c = \sqrt{\frac{p_x}{l y}}.$$

From the discussion of Case V. we see that c must be the ratio of the axes of the ellipse to which the pressures are respectively parallel. Hence if the arch be a semi-ellipse and O B be given, we have

$$\frac{OB}{OA} = c \therefore OA = \frac{OB}{c}.$$

From these data draw the curve of the soffit.

The thrust along the soffit at A

$$= H = p_y \rho_0 = w y_0 \rho_0.$$

At C or B it is $V = p_x \rho_1$.

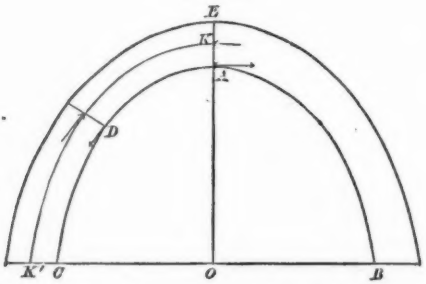
At other points it may be gotten from eq. (27) Case V.

We can determine the curve of pressures by a method similar to that used in the last case. Here, however, the curve K K′ will not be parallel to C A, since the thrusts along C A are not constant, but increase from A to C. Assume A K (Fig. 44) $= \frac{3}{8}$ A L, then the arch must be so proportioned that K K′ shall fall within the middle third.

If the arch C A B is not to be a *semi*-ellipse (as above assumed) but only a *segment* of one, a few trials will enable us to get the ellipse from the data already given.

The strictly true curve of equilibrium

FIG. 44.



required by earth pressure is the Geostatic arch.

5. An arch built with the curve discussed in *Case VI.*, is known as the Hydrostatic arch, from the fact that the loading there described is similar to the pressure of water upon a *vertical* arch.

For if M Y (Fig. 45) be the surface of the water, then its pressure on C A B is normal and proportioned at each point to the depth below M Y. This pressure, as has been shown, may be resolved into a vertical and horizontal pressure at each point, this vertical and horizontal pressure being equal in *intensity* to each other at every point, and also to the normal pressure of which they are the components.

The above form of arch may be applied in two cases.

(1) To bear the pressure of water or other liquid. Thus in the case of a river tunnel (such as those at Chicago) where the top of

the tunnel is practically on a level with the bottom of the river, we might use the hydrostatic arch.

The equation of the curve is

$$y\rho = y_0\rho_0.$$

The vertical load on the half-arch A B

$$= \int_{x_1}^{x_0} p\,dx = V = wy_1\rho_1 = \text{thrust along arch at B.}$$

The horizontal pressure against A B

$$= \int_{y_1}^{y_0} p\,dy = w\frac{y_1^2 - y_0^2}{2} = H = wy_0\rho_0. \quad (51)$$

The thrust along the arch is constant, or

$$T = H = V.$$

The rise A O ($= a$), the depth A Y ($= y_0$), and the radii at A and B (ρ_0 and ρ) are connected by the following approximate equations. The co-ordinates of B being x_1 and y_1, let

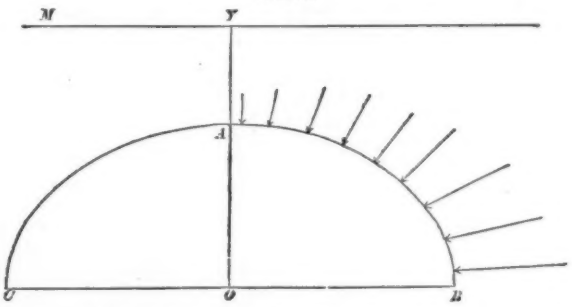
$$b = x_1 + \frac{x_1^2}{30a}. \quad \text{Then } y_0 = a\frac{a^2}{b^2 - a^2} \quad (52)$$

$$\rho_0 = \frac{y_1^2 - y_0^2}{2y_0} = a + \frac{a^2}{2y_0} = \frac{a}{2}\left(1 + \frac{b^2}{a^2}\right) \quad (53)$$

$$\rho_1 = \frac{y_1^2 - y_0^2}{2y_1} = a - \frac{a^2}{2(y_0 + a)} = \frac{a}{2}\left(1 + \frac{a^2}{b^2}\right). \quad (54)$$

The line of pressures in a hydrostatic arch, since T is constant, is *parallel* to the soffit, as in circular arches.

FIG 45.



Example.—Suppose the span to be 50 ft. (Fig. 46) and the depth A Y = 16 ft.

Find first the rise A O. In Eq. (52) $x_1 = 25'$ $y_0 = 16'$, and a few trials show that a = rise = 20′ about.

Hence

$$\rho_0 = 32\tfrac{1}{2} \text{ ft. and } \rho_1 = 14.1 \text{ ft.}$$

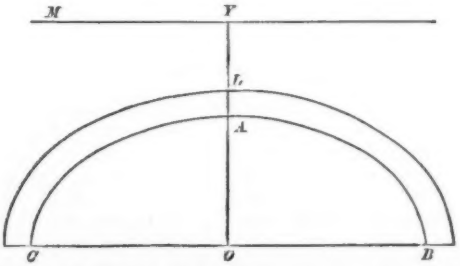
With these data describe the curve of the soffit—the radius at any other point besides A and B being given by the equation

$$\rho = \frac{y_0\rho_0}{y}.$$

The thrust at A = H = $wy_0\rho_0$. Here $w = 62.4$ lbs.

$$\therefore H = 32448 \text{ lbs.}$$

FIG. 46.



The rule for the depth of keystone in a single arch gives

Depth A L = $\sqrt{.12 \times 32.5} = 1.9$ ft.

This is ample. It only gives about 120 lbs. per sq. in. as the pressure at the crown.

T being = H, the depth of the arch-ring may be uniform.

(2) The hydrostatic arch is also used when the loading is homogeneous masonry up to the extrados M Y, *provided the spandrels be suited to sustain a horizontal thrust at each point of the arch equal to the vertical load at that point.*

As all stone or brick arches sink at the crown when the centres are removed, they will exert at other points an outward horizontal thrust. Now if we assume that this horizontal thrust is at every point equal in *intensity* to the vertical loading at that point, the curve of equilibrium under such a system of forces is the hydrostatic curve. This is the assumed condition of the forces acting in the Neuilly and other bridges of this class.

When the spandrels cannot be made firm and solid this form should not be used, but when they can be, as in the successive arches of a stone bridge, it is advantageous rather than otherwise, to have such a thrust from the arch against the spandrel; while the hydrostatic curve of given span and rise gives a greater *water-way* than the corresponding catenary would.

The catenary needs no resistance from the spandrel, being balanced under the vertical load alone.

Example.—Let the span be 100 ft. and rise 30 ft. Then the depth of loading at the crown (= A Y, Fig. 46) will be found from equation 52

$$= y_o = 7\tfrac{1}{3} \text{ ft.}$$

Then $\rho_o = 91.7$ ft.

Hence $H = v y_o \rho_o$ (putting $w = 160$ lbs.) $= 107600$ lbs.

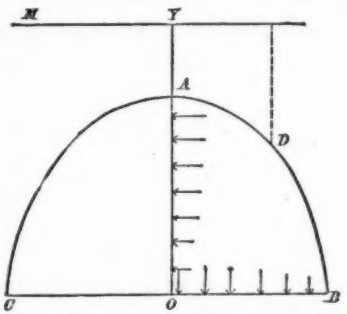
Depth of keystone

$$= \sqrt{.12 \times 91.7} = 3.3 \text{ ft.}$$

This gives a pressure of 32,280 lbs. to the sq. ft., or about 225 lbs. to the sq. in.

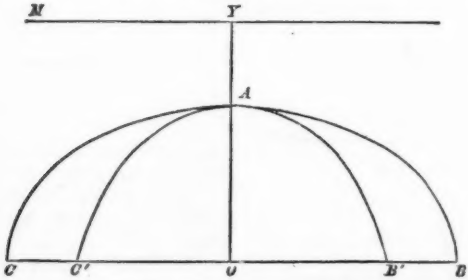
6. If the vertical forces vary as in the hydrostatic arch, and the *horizontal* are not equal to them, but differ at each point in a constant ratio, the curve of equilibrium (Fig. 47) becomes the Geostatic curve discussed in *Case VII.* This curve derives its name from the fact, that the system of pressures above described is similar to that exerted by a mass of loose earth against C A B. Let M Y = the horizontal surface of the earth; then at each point D of the arch there is a vertical pressure of intensity (p'_y) proportional to the depth (y) of D below M Y, and a horizontal pressure whose intensity is less than p'_y in a constant ratio,

FIG. 47.



or $p'_x = c^2 p'_y$

FIG. 48.



(c^2 being taken to represent the ratio of the intensities).

Assume a hydrostatic arch whose vertical dimensions shall be identical with those of the geostatic arch, and whose span (C B) (Fig. 48) shall be connected with the span of the geostatic arch (C' B') by the equation

$$C B = \frac{C' B'}{c}. \qquad (55)$$

The intensity of the vertical pressure (the horizontal is like it) in this hydrostatic arch must be

$$p_y = cp'_y .$$

From these data deduce a hydrostatic arch, and then pass by parallel projections to the required geostatic arch.

Equations (35) (36) (37) (38) give the values of the quantities needed in discussing the Geostatic arch.

Example 1.—Let the span of the geostatic arch (C′ B′ = 100 ft.) be given; also the depth of the loading (A Y = 20 ft.); also the ratio of the pressures ($c^2 = \frac{1}{3}$); and the weight of a cubic ft. of the loading $= w = 100$ lbs. Whence

$$p'_{y_0} = wy_0 = 2000 \text{ lbs.}$$

Then since

$$\text{C B} = \frac{\text{C}' \text{B}'}{c} = \frac{100}{\sqrt{\frac{1}{3}}} = 172.4 \text{ ft.}$$

$$cw = 58 \text{ lbs.}$$

$$p_{y_0} = cp'_{y_0} = \sqrt{\tfrac{1}{3}} \cdot 2000 = 1154.7 \text{ lbs.}$$

We find from equations (52) (53) (54) for the hydrostatic arch

$$\text{Rise} = a = \text{O A} = 57.7 \text{ ft.}$$
$$\rho_0 = 140.93 \text{ ft.}$$
$$\rho_1 = 36.3 \text{ ft.}$$
$$\text{H} = \text{V} = \text{T} = p_{y_0}\rho_0 = 1154.7 \times 140.93 = 162.700 \text{ lbs nearly.}$$

In the geostatic arch we have from equations (35) (36) (37) and (38)

Thrust at B = V′ = V = 162700 lbs.
" A = H′ = cH = 94300 lbs. nearly.
$\rho_0' = 46.97$ ft. $\rho_1' = 62.65$ ft.

Example 2.—Suppose the span = 100 ft. depth. A Y = y_0 = 20 ft. and rise, a = 30 ft. given; to find c and thence the hydrostatic arch.

From equation (52) we find

$$b = 40.71,$$

and thence in same equations $x_1 = 39$. Hence the span of the hydrostatic arch

$$= 2x_1 = 78 \text{ ft.}$$

And as c.CB = C B′

$$c = \frac{100}{78} = 1.28.$$

Then proceed as in the last example. In this example the hydrostatic arch is the smaller of the two.

The line of pressures in a geostatic arch is found as it was in the elliptic.

The geostatic is the true curve of equilibrium under earth pressure, but when A Y (Fig. 48) is great compared with A O, it approximates the ellipse described through the points C A B′ as already stated.

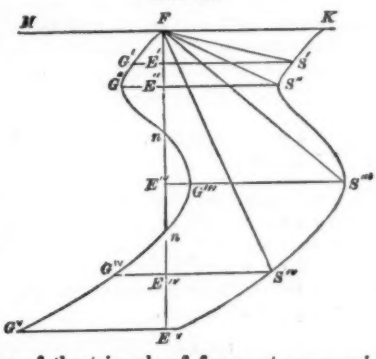
7. Convenience, or other reasons, will often dictate the form of the arch without reference to the loading, and again, necessity may make the vertical load different from any and all the cases we have discussed. In such instances Case VIII. will enable us to determine the character and amount of the horizontal forces which must be applied through the resistance of the spandrel, when once the form of the arch and the vertical load are known.

When the horizontal forces thus required are *thrusts* directed against the arch, it is generally possible so to build the spandrel that the arch may be secure, but when they are the opposite, or *outward pulls* on the arch, then it is difficult to insure stability, as to do so requires tension between the arch and the spandrel. In such cases it is best to change the form of the arch.

The discussion of Case VIII. of cords, enables us to determine the necessary data in the case of similar linear arches under similar loads.

Fig. (50) gives the geometrical construc-

FIG. 50.



tion of the triangle of forces at every point of the semi-arch A B (Fig. 49).

We may discuss a given linear arch C A B under a given vertical load, by determining:

1. Thrust at crown; which is

$$\text{H}_0 = p_0\rho_0. \qquad (56)$$

2. Total horizontal thrust required on any arc A D′, A D″, etc. This, from equation (42), is

$$\text{H} = \text{H}_0 - \text{V} \cot. i. \qquad (57)$$

If this be negative the spandrel must exert a *pull* instead of a thrust.

On the half arch A B the above equation becomes

$$H_1 = H_0 - V_1 \cot. i_1. \qquad (58)$$

On any arc B D^{v}, counting from B upwards, the total spandrel thrust is

$$H_1 - H = - V_1 \cot. i_1 + V \cot. i \qquad (59)$$

This last expression has at least one maximum value corresponding to some arc B D. In the Fig. (49) this value corresponds to the arc B D$'''$.

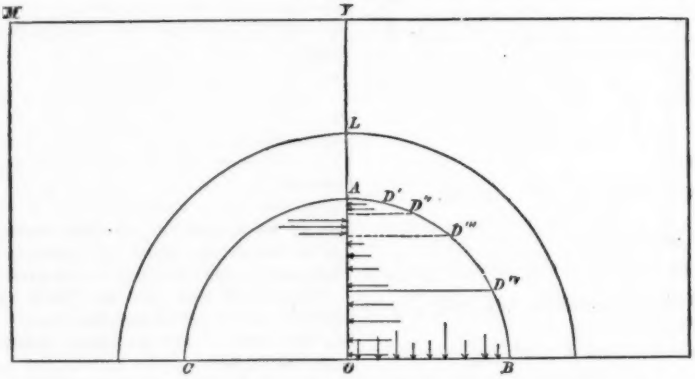
Let this maximum value be denoted by H_m and let i_m = the inclination at D$'''$. Then

$$H_m = - V_1 \cot. i_1 + V \cot. i_m = E''' G'''. \qquad (60)$$

(Fig. 50)

D$'''$ is known as the "point of rupture."

FIG. 49.



There the action of the spandrel ceases to be a thrust, and must, above that point, for some distance at least, become tension.

3. The *intensity* of the horizontal spandrel thrust or pull in any layer (as between D$'''$ and D^{v}) is from equation (43)

$$p_x = - \frac{d\,H}{dy} = - \frac{d\,(V \cot. i)}{dy} = - \frac{d\left(V \frac{dx}{dy}\right)}{dy}.$$

When H is positive (that is thrust) p_x is negative, as it should be, since it is equal to the *increment* of the abscissas of the curve F G G$''$, etc. (Fig. 50), and these increments are decreasing from G$''$ to G^{v}.

At the point of rupture

$$p_x = 0. \qquad (61)$$

We can determine the point of rupture in three ways: First, by constructing the Fig. (50) and finding the inclination (i_m) corresponding to the maximum abscissa E$'''$ G$'''$. Secondly, by substituting the various values of i and V in the value of

$$(H_1 - H) \text{ (eq. 59)},$$

and getting the maximum value of the expression. The i which gives this maximum value corresponds to the point of rupture. Thirdly, by solving equation (61) $p_x = 0$.

4. The thrust along the rib at every point is from equation 40,

$$T = V \text{ cosec. } i, \qquad (62)$$

and it is represented by the inclined lines F S' F S$''$, etc., Fig. (50).

The *horizontal component* of this thrust is

H_r = V cot. i = the abscissas of K S$'$, etc.,

which are always equal to H_0, the thrust at the crown *minus* the spandrel thrust between A and the point in question

$$\therefore H_r = V \cot. i = H_0 - H. \qquad (63)$$

This is evidently a maximum at the point of rupture, or, since at the point of rupture,

$$H = H_1 - H_m,$$

we have

$$H_R = H_0 - H_1 + H_m.$$

But

$$H_0 - H_1 = V_1 \cot. i,$$

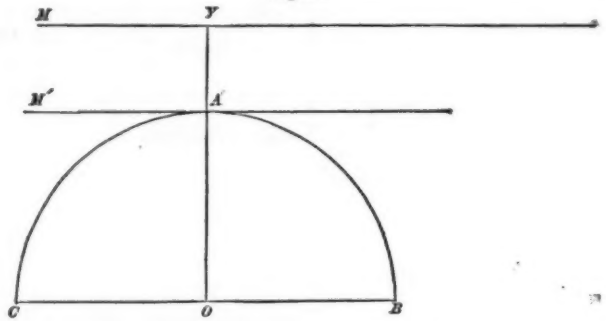
$$\therefore H_R = V_1 \cot. i_1 + H_m. \qquad (64)$$

This horizontal thrust of the rib at D$''$ is therefore to be balanced by the horizontal reaction of the abutment at B (= V_1 cot. i_1) togther with the resistance of the spandrel

between B and D‴ (= H_m). When the arch is vertical at B, $V_1 \cot. i_1 = 0$.

5. In single arches it is necessary to know the point of application of the resultant of the forces represented by ($V_1 \cot. i_1 + H_m$) in order to determine the stability of the abutments. Take moments with reference to the axis of abscissas M Y.

Fig. 51.



Then if y_R = ordinate of point in question, and y_m and y_1 be the ordinates of D‴ and B, we have

$$H_R y_R = (V_1 \cot. i_1) y_1 + \int y d H$$

$$= (V_1 \cot. i_1) y_1 + \int_{y_m}^{y_0} y p_x \, dy.$$

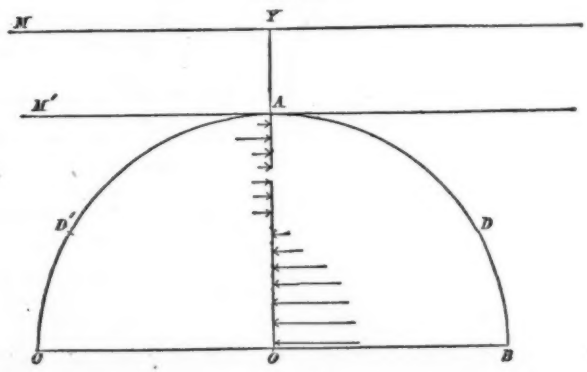
$$y_R = \frac{(V_1 \cot. i_1) y_1 + \int_{y_m}^{y_1} y p_x \, dy}{H_R}. \quad (65)$$

In this we neglect the spandrel forces above D‴ so far as they affect the stability of the abutment. This can be done with safety.

The line of pressures and depth of keystone are determined as heretofore.

Example 1. Let the assumed form of the soffit be a semi-circle, and let the loading consist of the arch and backing of homogeneous masonry carried up to a horizontal "extrados" M Y (Fig. 51).

Fig. 52.



Place the radius of the arch = r

Depth A Y = $a r$

Heaviness of the material = w

Take the origin of co-ordinates at A and express the co-ordinates in terms of the inclination i of the arch as on p. 217 *Rankine's C. E.*

Then

Thrust at crown = $H_0 = p_0 \rho_0 = (war)\, v = war^2$

Vertical load on any arc = $V = wr^2 \left\{ (a+1) \sin. i - \frac{\cos. i \sin. i}{2} - \frac{i}{2} \right\}$

Spandrel thrust on any arc A D

$$H = H_0 - V \cot. i = wr^2$$

$$\left\{ a - (1+a)\cos. i + \frac{\cos.^2 i}{2} + \frac{i \cos. i}{2 \sin. i} \right\}$$

On A B this becomes (since the arch is vertical at B and C)

$$H_1 = wa^2 = H_0$$
$$\therefore\ H_m = V \cot. i_m$$

Intensity of spandrel thrust

$$\therefore\quad p_x = -\frac{d\,(V \cot. i)}{dy} = wr$$
$$\left\{ (1+a) - \cos. i - \frac{i - \cos. i \sin. i}{2 \sin^2 i} \right\}$$

The point of rupture is found by putting $p_x = o$ and finding the value of i_m by trials. As a first approximation

$$i_m = \text{arc. cos.}\ \frac{1+3a}{2}$$

Thrust along the rib $= T = V \operatorname{cosec} i$. At B this is

$$V_1 = wr^2 \left(a + 1 - \frac{\pi}{4} \right).$$

So

$$H_x = V_1 \cot. i_1 + H_m = H_m = wr^2$$
$$\left\{ (1+a)\cos. i_m - \frac{\cos.^2 i_m}{2} - \frac{i_m \cot. i_m}{2} \right\},$$

and

$$y_x = \frac{r^2}{H_x} \int_{i_m}^{90^\circ} p_x \sin. i\,(1 - \cos. i)\, di.$$

Example 2.—Let

$$r = 20'\ A\ Y = 2.5'.$$

Then

$$a = \frac{2.5}{20} = \frac{1}{8}\quad w = 150 \text{ lbs.} \quad \text{(Fig. 52.)}$$

Then

$$H_0 = war^2 = 7500 \text{ lbs.}$$
$$V = 60000 \left\{ \frac{9}{8} \sin. i - \frac{\cos. i \sin. i}{2} - \frac{i}{2} \right\}.$$

$$\text{At B, } V = 60000 \left\{ \frac{9}{8} - \frac{\pi}{4} \right\} = 20376 \text{ lbs.}$$

Angle of rupture

$$i_m = \text{arc. cos.}\ \frac{1 + \frac{3}{8}}{2} = \cos.^{-1}.6875 = 46^\circ\ 34'$$

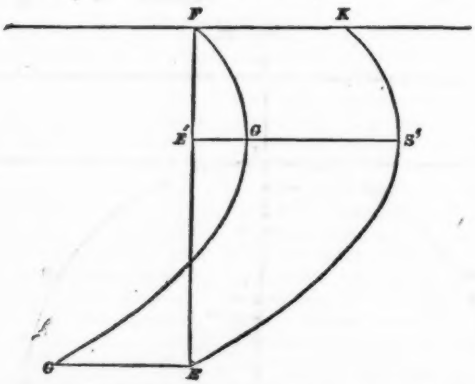
$$H_x = H_m = 60000$$
$$\left\{ \frac{9}{8}(.6875) - \frac{(.6875^2)}{2} - \frac{.81 \times .947}{2} \right\} = 8154 \text{ lbs.}$$

(Fig. 53) shows the manner in which the forces vary. From A to D (Fig. 52) there must be a pull in the spandrel to produce equilibrium. The total amount of this pull is small, being

$$= 8154 - 7500 = 654 \text{ lbs.}$$

To rid the arch of it, so that the part D' A D shall either be balanced under the vertical load alone or exert a thrust out-

Fig. 53.



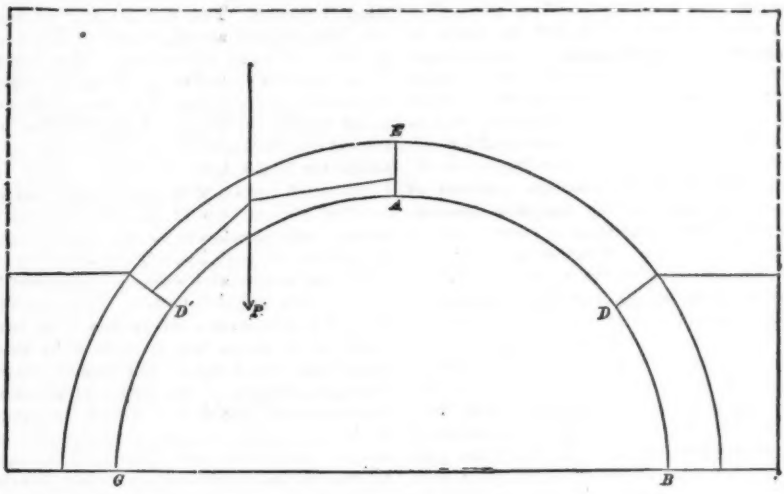
wards, instead of a pull inwards, we *flatten* the arc D' A D. A few trials will determine this flattening near enough for practice.

Thus if D' A D (Fig. 54) is to be balanced under the vertical load alone, find the centre of gravity of the section D' A and its load. Draw a vertical line P through this point, then if we can draw a line from any point in the middle third of the joint D' parallel to the tangent to the arch there, and from its intersection with P draw a line parallel to the arch at A which will intersect A L within the middle third, then the extreme points of the line of pressures in the section A D' will be within the middle third, and the line of pressures will generally be altogether within it.

The new radius required for the arc

D' A D may also be determined roughly by putting $H_a = war^2 = H_B$ and thence getting r' since, if D' A D is to be balanced under vertical load alone, the horizontal thrust at every point of it must be the same and $= H_B$, the thrust at D' and D.

FIG. 54.



FORCE AND MATTER.

From "The Engineer."

Few men of science venture to teach that force can have existence apart from matter. To Faraday, we believe, is due the first hint at a possible conception of pure force. His utterances on the subject were brief, and intended as a species of abstract theory of magnetic influence. They have scarcely modified the current of educated thought; and at this moment no adequate conception of the existence of abstract force is to be found in the circles of science. Yet it is not, we think, impossible to form an idea of the existence of pure force; indeed, it may almost be said that we have daily evidence that force does exist apart from matter, although the presence of matter is necessary to render it evident to our senses. Gravity is, in one sense, a pure force. It is an invariable condition of, and totally inseparable from, matter, in the sense that no matter exists which is not subject to the action of the force known as gravitation. But the theorem will not work both ways. We know that masses of matter attract each other; but it has yet to be proved that a mass of matter does not exert the force of attraction, although no other mass of matter is subjected to its influence. There is probably nothing more mysterious in the whole range of material phenomena than the subtle influence which sets space at defiance, and, without any tangible link, couples the universe in bonds that cannot be broken. A force which can neither be intercepted, diverted, nor modified in the smallest possible degree, by any of the gigantic agencies of nature or the trivial influences of man's art. Gravitation is absolutely independent of all other forces, and in this respect it is to some extent isolated and unique. It is, we think, scarcely possible to realize the operation of gravitation without arriving at some crude and imperfect conception of pure force apart from matter; and however imperfect that conception may be, it will be found useful in solving some of the great problems presented to us by the operation of natural laws. Let us take it for granted, however, that force does not exist without matter,

and come at once to the purpose with which this article is written. Our object is to call attention to the fact that no one has yet attempted to show the relation that exists between matter and force as regards relative quantity. It was impossible in the earlier ages that any attempt should be made to determine this relationship In the younger years of the world, manifestations of great force were always associated in men's minds with enormous quantities of matter. But as knowledge, and especially chemical knowledge, has extended, the fact begins to obtrude itself, that the absolute quantity of matter necessary to the tangible development of gigantic exertions of power may be excessively minute. Whether it is or is not possible that an accurate numerical demonstration of the relations of force and matter in the abstract will ever be arrived at, it is not for us to say. Possibly the ultimate atom may yet be found, and its measure of possible work on another atom defined; but it is certain that at present both have eluded the grasp of the highest intellects of the nineteenth century. Tyndall has gone far to determine the work done by an atom under certain conditions, but he has not attempted to define the condition of maximum atomic work, and nothing in the whole range of our subject is certainly known, except that under given conditions extremely minute quantities of matter can exert forces which almost baffle conception. A very crude popular illustration of the association of great force with little matter is afforded by gunpowder. But gunpowder really furnishes but a very indifferent example of the amount of energy which may be exerted by minute quantities of matter. A tiny drop of that curious compound, chloride of nitrogen, the precise nature of which has yet to be determined, has been known when touched to explode with such violence as to split the heavy leaf of a solid oak laboratory table and leave the apartment a wreck. Gunpowder beside this fluid is an inert substance. Fulminate of silver and nitroglycerine supply other illustrations of the power which minute quantities of matter possess under suitable conditions of rendering manifest the exertion of mighty forces. It is unnecessary, however, to seek for examples among the more recondite productions of the chemist. It is not easy to find a more noteworthy illustration of this combination of much force with little matter than that afforded by coal. One pound of good coal will liberate in combustion 14,500 units of heat. This is very easily written and remembered, but we dare to say that not one of our readers out of the hundred has ever attempted to realize what it means. The British unit of heat has been defined as equivalent to 772 foot-pounds — Joule's equivalent; the power stored up in a pound of good coal therefore represents the exertion of a force sufficient to lift $14{,}500 \times 772$, or 11,194,000 lbs., or almost five thousand tons, a foot high, or a single ton to a height of nearly a mile. Is it too much to say, with such a fact before us, that the quantity of matter required to render force manifest is almost infinitesimal. A particle of coal, indeed, so small as to elude our senses with ease, is competent to exert a very tangible power. The 14,500th part of a pound of coal is less than one-third of a grain, yet it suffices to store up a force which would lift nearly 7 cwt. through a height of one foot. If a pound of coal were divided into 11,194,000 separate parts, a powerful microscope would be necessary to detect one such part, and yet each represents as much energy as would raise a pound weight a foot high. We need seek no further for evidence that the existence of matter in quantities tangible to our senses is by no means necessary to the development of power; and we are led to ask once more whether any point can be defined where matter ceases and force remains; or is it certain that without matter in some shape or form force can have no existence, manifest or abstract?

The relations subsisting between force and matter have been powerfully brought home to practical engineers by the Blackburn boiler explosion. It is not our intention here to say anything of the causes which may have induced the catastrophe, nor are we about to enunciate any theory of boiler explosions. It is impossible, however, to read with care the report which we published last week, without feeling that a puzzle is presented to us, which can only be explained by the fact that very small quantities of matter may, under certain circumstances, manifest an energy apparently altogether incommensurate with the mass of matter employed. We have no means of knowing with accuracy the weight of water contained in the two boilers at the time of the explosion; probably it was about 25 tons. This water was heated to about 324 deg. Fah., the temperature

corresponding to an absolute pressure of 95 lbs.—80 lbs. safety valve load. Each pound of water therefore represented an energy of 324×772=250,128 foot-pounds; but all this energy was not available for destructive purposes. When the boilers exploded the temperature fell instantaneously to 212 deg., leaving to be accounted for 112 deg. If this were immediately expended in one way, about one-eighth of the total weight of water in the boiler would have been converted into steam at atmospheric pressure, and no doubt in this way by far the larger proportion of the stored up energy in the boiler was utilized, and but for the invariable occurrence of the flashing of water into steam when pressure is relieved, the consequences of a boiler explosion would be more fearful than it is perhaps quite possible to realize. Here, however, as the capacity of water for storing up energy is great, that which constitutes the dangerous element in heating water under pressure becomes in some measure a means of safety. In this respect the behavior of water is totally different from that of gunpowder; when a charge of powder is fired in a gun the entire energy stored previously in the powder is exerted on the gun and the projectile. When a boiler explodes, a very considerable portion of the energy previously concentrated in the water is expended, not on the boiler, or building, but in converting more water into steam at atmospheric pressure, and it thus happens that although the destruction wrought by the explosion of a large boiler may be fearful, matters are never as bad as they would be but for the remarkable property possessed by water, of instantaneously utilizing its stored up energy in the comparatively harmless way of flashing a portion of itself into low-pressure steam. All the latent energy in the boiler was not thus expended, we know; had it been, then the mill would not have been wrecked, and no one would have been killed. A portion was expended in doing work—very disastrous work, no doubt, but none the less real. And this brings us at once to the puzzle, or puzzles, to which we have referred. We hear of stones being flung long distances, while a flue was lifted high in the air and fell on the roof of the weaving shed. Let us take this flue as typical, and ask ourselves how it was raised? The obvious answer is, "Oh, the steam carried it there." Precisely; but how did the steam carry it there? When a projectile is discharged from a gun an enormous pressure is exerted on its base for a considerable portion of time; but what are we to think of the nature and mode of action of the force which lifts a flue out of its place after the containing shell has been rent to atoms, and sends it flying through the air? Literally, not more than a few pounds of steam could find access to the flue to do the work; its surface was too small. Taking the flue at 30 ft. long, and just allowing a strip of its surface 3 ft. wide as an effective basis for the action for the steam, we have only 90 ft. surface. A body of steam at 80 lbs. pressure and 1 ft. thick over this surface would weigh about 2 lbs. only. It is impossible to imagine a sufficient velocity imparted to this 2 lbs. of steam to enable it in any way to impinge on the flue and thus propel it through the air. Nor shall we be helped if we say that the pressure beneath the flue was unbalanced the moment the shell burst, and this unbalanced pressure lifted it. The pressure must have operated for a considerable time after the flue started on its flight, otherwise no energy could have been stored in it to enable it to continue its ascent. To what then are we to look as the direct cause of the ruin which attends a boiler explosion? Where is the link between the energy stored in the water and the walls blown down at a distance, the scattered bricks of the seating and the flying boiler plates? We do not think it too much to say that these questions have never been answered, and that the effects developed are perhaps after all manifestations of the exertion of force by the aid of very minute quantities of matter, operating in a way which is not quite understood. The cause of a boiler explosion is one thing, the cause of the effects of an explosion is quite another. We hold now, as we have always held, that there is nothing occult about the reason why a steam generator bursts. Neither, perhaps, is there anything mysterious about the flying of plates and the loss of life, and the ruin of buildings; but it is quite certain that no solution yet put forward has proved capable of that accurate numerical demonstration which can alone insure its acceptance. That ruin ensues when a boiler bursts we know, but we do not know whether a flying brick flies because it has been subjected to intense pressure acting through a limited space for a short time, or whether it is carried on a

blast of steam as a leaf is carried by the wind, or whether it is driven by energy transferred from a mass of water moving, and whose movement the luckless brick has checked. Nor is it quite certain—although, in deference to accepted opinion, we have spoken as though it were certain—that the first effort of energy set loose in the rent boiler is to convert more water into steam, and not to manifest itself in some other way which is apparently occult, but only so because very little is really known about the manifestations of energy, or the bond which exists between force and matter.

TARGET'S SEWERAGE SYSTEM.

From "Engineering."

The multiplicity of plans which have been brought out for the purpose of removing and disposing of the waste or refuse of human life, together with that of the lower animals, is an evidence of the difficulty which surrounds the entire question. This difficulty may be viewed in its mechanical, chemical, and financial phases, and each of these has its complications, owing to the variety of local conditions which have to be satisfied. In the case of places situated near the sea, a long sewer running to a point, a little below the low water level, is generally depended on to get rid of all liquid refuse, while the solid matters, such as ashes, etc., are generally used on adjacent land, or for brick-making. Towns placed near rivers, have, as a rule, in all parts of our own and other countries, used the stream as the receptacle of refuse of all kinds; and in places where no adjacent river or even brook is available, all the liquid refuse has been thrown into cesspits or ponds, or, in fact, any hollow place, without the slightest reference to the dangerous consequences that might ensue. In regard to the "dust-bin" refuse, including not only ashes but decomposing vegetable matter, etc., a glance at some of the vacant ground in the suburbs of London and other large towns, will at once explain its disposal by a common notice that "Dry rubbish may be shot here;" and on this rubbish a large number of new streets has for years been built to the detriment of public health.

The sewage question, *per se*, has been largely dealt with in our present and preceding volumes, chiefly in regard to the water-closet, midden, and other recipients of refuse, and the individual means that have been proposed, by irrigation, precipitation, and other methods, to deal therewith, have been explained. In the present article we propose to deal with the subject in a comprehensive point of view, even at the risk of apparent repetition of some matters which have been, in previous articles, somewhat fully discused. For this purpose we may first inquire as to what refuse has to be dealt with, in all classes of towns, whether of a social, agricultural, or manufacturing character.

Wherever the water-closet system has been adopted there has been a large dilution of the urinary and fæcal matter prevalent, dependent partly on the amount of the water supply afforded to each house, but perhaps still more so on the habits of its inhabitants. As a rule, the intermittent system is for the present the mode of supply in many parts of the United Kingdom, but now the constant supply is being gradually adopted, attended with an actual saving on the previous amount of water used or wasted. This is a matter of no surprise considering that where butts and cisterns have prevailed, the tenants, generally, have considered it their duty to use all the daily supply afforded them, and besides, there is the loss caused by defective ballcocks, taps, etc. This loss to the water companies, however, may have resulted in social benefit by the continual flushing of the sewers which has consequently taken place.

But in many places the water-closet system is all but unknown, and hence the use of privies, middens, etc., in which the human excrementitious matter is literally stored, in each household, perhaps for months or even years. The ash-pit is either separate from, or adjacent to, the privy; the other liquid house refuse being usually cast into the streets to run down the sewers or to fester during the hot weather in the open air, poisoning the inhabitants on either side of the street. Yorkshire, Lancashire, and a large proportion of Scotland present this in its worst state, at the present

day. The only means of removing all classes of refuse in such places from the house is that of cartage, which is at the same time expensive, a dangerous nuisance, and very imperfect in its action. All or most of the agricultural districts also fall under this category.

Lastly, the disturbing element of manufacturing operations appears. Generally these are never carried on when sewers alone can be depended on for conveying away the refuse, except as an adjunct to adjacent rivers, which are made directly or indirectly the recipients of a series of waste products which it would defy the most profound chemist to enumerate, let alone describe. Usually in all manufacturing towns the privy, cesspool, and ash-pit are the chief receptacles of house refuse, with a mere sprinkling of water-closets.

From these sources we derive all the refuse which engineering and chemical science and art have to contend with in solving sanitary questions. Consequent on the varying conditions, qualities, localities, etc., of such refuse, numerous schemes have been adopted or proposed, which may be shortly stated as follows: For the purification, disposal, and utilization of sewage, those of irrigation, filtration, and precipitation; for dealing with urine and excreta alone, Moule's, Goux's, and similar dry-closet systems, all of which require the separate removal of ashes; and the latter both the separate removal of ashes and house-slops; while last may be mentioned the tub system, by which all the house refuse is removed weekly, or at shorter intervals, from the place of deposit to be subsequently disposed of as manure, etc. Scott's system, as now practised at Ealing, and experimented on at Birmingham, has the distinctive feature of dealing with the sewage by using lime as a precipitant, and converting the resulting residue into cement; the house ashes he, however, leaves untouched. In this *résumé* of all the leading systems we have omitted both names and details, as they will be found *in extenso* in our two last volumes.

By careful examination of all the existing schemes of removing, disposing, or utilizing sewage, excreta, ashes, etc., it will be seen that each has only a partial adaptation to the entire purpose, leaving something to be supplemented by separate methods, excepting perhaps the tub system, as followed at Rochdale, etc., by which all except manufacturing refuse is removed, that being left to pass into the sewers, together with the rainfall and street waterings.

To meet all the necessities of the case we have now to draw attention to a very comprehensive scheme suggested and patented by Mr. Felix Target, of which a general outline was given in our two preceding volumes by means of letters furnished by that gentleman. He divides his method into two departments, namely, that of closet receptacles, and the removal of the deposit to works; in which, secondly, such deposit is converted into a portable concentrated manure in the form of an ammoniacal salt.

He proposes to collect, or rather receive, the liquid and solid excreta, in such a manner that the urine shall be voided in a separate chamber from the fæces, under the assumption that the two are naturally voided separately at an angle of about 45 deg. He employs in such closets an absorbent for taking up the fæcal product, using for the purpose straw, chaff, screened ashes, peat, etc. This receptacle he terms an "eccentric divisor," or "E. C. closet." The mechanical arrangement of this is such as to permit it to be placed under any already existing privy seat. The receptacle may be removed every week or fortnight, according to the extent of its use. For indoor use, sick-rooms, etc., an arrangement is made by which, at each time of use, the disinfection or deodorization of the excreta is effected. This is made automatic by providing a movable seat hung on sash centres, depressed in front and raised at the back. By means of an india-rubber spring, a certain amount of disinfectant matter is caused to fall on the fæces, at each time the "closet" is used, when the occupier removes from the seat; and the action is repeated on each occasion of the seat being used, provision being made for about 100 times. The urine is collected apart from the fæces. The inventor suggests the use of sawdust as the absorbent combined with any kind of disinfectant. The advantage of this arrangement consists in its not being liable to get out of order, and consequently its action is regular and to be depended on. For collection from several houses, built in blocks, Mr. Target suggests an arrangement by which the whole essential features of the plan can be carried out, but avoiding the necessity of separate or house-to-house collection. His

great object, as will be subsequently shown, is that of carefully collecting the urine apart from the fæcal matter. In respect to the collection of ashes, kitchen refuse, etc., he proposes daily calls on the part of the scavenger, whose approach should be announced by a bell, the house refuse being placed outside of the house in a tub or box, and thus the dust-bin would be avoided To prevent any annoyance in regard to emptying closets separately, he suggests that pipes may be laid from the closets of several houses into a common cistern, whence the urine, etc., may be pumped into carts for their removal. This method would of necessity be much more economical than that of house-to-house collection. But besides, there is the advantage of preventing the overflow of tubs, now used in some places, as a system which occasions much nuisance, dirt, and even danger to health.

Thus far we have described the chief points of Mr. Target's plan in regard to the collection and removal of house refuse, but the most important part, that of its conversion into a profitable commercial product, has to be dealt with.

For successfully carrying this out Mr. Target depends on the fact that the fæcal matter is of much less value than the urine. He, therefore, bases all his methods on their separate collection in the closets or receptacles at the moment of their voidance, dealing with fæcal as a solid, and the urine as a liquid. He estimates, making various allowances for loss, etc., that 24 oz. of mixed excreta may be collected daily from each individual in an average population of, say, 100,000 persons, which would consequently give, daily, about 11 tons 3 cwt. of fæcal matter to 58 tons 12 cwt. of liquid matter (urine), or in round numbers something like 70 tons.

It is presumed that each of these products has been collected separately, by means of the divider closet, the fæces having been mixed with the absorbents and disinfectants. The receptacles when full are to be conveyed in closed vans to the works. The fæcal or solid matter is then to be incorporated with coal tar, and then moulded by suitable machinery into blocks or bricks. These blocks are then to be air-dried, in the manner usually followed in house-brick-making, and thus, in a few days, they will become suitable fuel, to be used in place of coal for further operations. It will thus be seen that Mr. Target proposes to utilize all the carbon of the human excreta for heating purposes, and thus to economize this cause of expenditure.

The next step is that of treating the urine so as to extract from it, in the most economical and effective manner, all its nitrogen in the form of ammonia, and the subsequent conversion of this into sulphate of ammonia as a manure now so greatly in request; or, if desirable, to produce ordinary sal-ammoniac, which is largely employed in metal and other manufactures. The urine is heated with caustic lime in a closed apparatus and the ammonia given off is received into sulphuric acid, if sulphate of ammonia be required, or into hydrochloric acid if sal-ammoniac is to be produced. Generally the plan followed would be that adopted at gas works for similar purposes; but Mr. Target's method of economizing fuel, by using the "bricks" made from the fæces, and the gases evolved in their combustion, as a source of heat, will nearly, if not entirely, do away with the use of coal. In fact, he calculates that the 11 tons of fæcal matter mixed with an adequate proportion of tar, as already described, would render any other fuel needless. This is a most important point, because the cost of the fuel is the element on which the success of the entire plan, in a commercial point of view, depends. Equally so is the method by which the heat produced is applied, and to effect this in the best manner Mr. Target has invented a still in which all such conditions are rigorously carried out.

Next comes the important point of the financial part of the affair. Entering into careful calculation of the expenses of collection, removal, and manufacture, including all items of expenditure for wages, etc., Mr. Target puts the cost of the conversion of the excreta of a population of 100,000 persons at £50 per day, which would be covered by the amount of sulphate of ammonia daily produced, leaving many other products that might be utilized, including phosphates, alkaline salts, etc., derivable as residual products both from the fæces and urine.

We have thus epitomized the leading principles of Mr. Target's method, as applicable to large towns. Some of the details are not new, but the combination of them and others presents several novel features, but especially that of economy in manufacture. By all previously described methods, a large proportion of the nitrogeneous products of

the human system is lost, and to prevent such loss is Mr. Target's object. It is evident that the whole system must be subject to certain modification, according to the locality in which it is to be applied. In districts where the population is highly fed, the products will be much more in quantity and therefore in value, owing to the presence of more nitrogenous matter than could be gathered from poorer districts. In some places, slack coal, being very cheap, might be used, and the fæcal solids be sent out as dried manure, while in others they would be employed exclusively as fuel. It is a great advantage of the plan that it can be used under such varied conditions. Another and highly important point is that the sulphate of ammonia formed is of such high commercial value as to make the question of its cost of carriage insignificant, no matter what the distance may be, and in this it compares most advantageously with all the manures yet produced by chemically precipitating sewage, for they generally contain, at least, three-fourths of their weight of matter positively valueless and inert. The sulphate of ammonia, again, is a product that does not change by keeping, and its demand in the market is almost always in excess of the supply. It at present fetches from £15 to £17 per ton.

We are not aware of a single instance in which the disposal of sewage and other refuse has yet been effected but at a cost to the ratepayers, except perhaps in one or two cases in which irrigation has been followed rather as a fancy than a business. All the chemical schemes have notably failed, and the tub system has entailed much cost where it has been adopted. It is true that the chief problem is not so much how to turn the sewage of towns into money making, as how least injuriously and with most economy to get rid of it. But if this can be done in a manner which, while affording no profit, may at least cover the entire cost, the advantage will be enormous. This Mr Target proposes to obtain. The authorities of most of our towns are utterly at a loss how to get rid of their sewage, and this new method, or rather combination of methods, affords a good chance of solving the problem in a sanitary and financial point of view.

METROLOGICAL REFORM.

From "The Engineering and Mining Journal."

We regret that we have not space for the publication at length of two memorials issued by the American Metrological Society, addressed to Congress and submitted for signature to all persons who sympathize with their object. In one of these memorials the desirability of a uniform system of weights, measures and moneys, is set forth, and reference is made to the fact that the inhabitants of France, Belgium, the Netherlands, Spain, Portugal, Italy, Switzerland, Roumania, the entire German Empire, and, for purposes of foreign commerce, the Austro-Hungarian Empire also, enjoy the benefits of uniform metrological standards, and that the same is the case in all the countries of South America and in those of North America south of the United States. Great Britain and this country are almost the only ones that hang back, and there are numerous indications that they cannot long resist the general tendency. Ten years ago, the optional use of metric weights and measures was legalized by the British Parliament in Great Britain and Ireland; and in legislating for India and its population of 150,000,000 souls, the British authorities have actually adopted the metric system.

Congress has already taken several steps in the same direction. In 1866, the use of metric denominations was legalized and the General Government has caused to be prepared and delivered to the several States accurate copies of the metric standards. Moreover, in the coinage act of last year the weights of all silver coins of the United States, except the trade dollar, are stated in metric denominations. This memorial asks for such additional legislation as shall make efficient the measures already taken, and familiarize our people with the metric system in ways not calculated to disturb their ordinary business. Laws are asked for, which shall make practicable as well as legal the use of the metric system of weights and measures in the estimation and computation of customs-duties in the custom-houses of the United States; which shall make it obligatory upon the Post-Office Department of the United States to

assess postages on matters transmitted through the mails in accordance with the provisions of the metric postal act of 1866; which shall require, in the reports of all the great public works conducted under the authority of the Federal Government, numerical statements involving dimensions, or quantities of any kind, to be made in metric denominations as well as in those of the metrology in common use in the country; and which shall extend this requisition to statistical and other documents involving statements of quantities, which may be issued under authority of any of the departments of the Executive Government.

The other memorial refers to coinage, and asks that the legal weights of our gold coinage, which are already metric within a fraction exceeded, for the smaller coins, by legal tolerance, may be made entirely metrical, so that the amount of pure gold contained in the gold dollar will be exactly one gramme and a half. This statement of the case is correct, but meagre. The numerous reasons for a change are not given with sufficient fulness; nor is it pointed out, that if the gold dollar contains exactly one and a half gramme of pure gold, then a three-dollar piece, nine-tenths fine, would weigh exactly five grammes. The coinage itself, therefore, as well as the amount of pure gold contained in it, would be commensurable with metric standards; and it would be easy, by printing upon each coin a statement of its weight, to make everybody familiar with the units of weight. This opens at once an easy road to international coinage. It is only necessary that the fineness of standard gold should be everywhere nine-tenths (as it is everywhere already except in Great Britain), that the weight of pure gold in coins should be given on the coins in metrical units, and that the mints of civilized countries should do honest work. The immediate result would be, that the gold coins of nations adhering to this plan could safely be made legal tender in exact proportion to their weight. For instance, in this country foreign coins could be accepted without indirect calculations of value, on the simple principle that every three grammes of pure gold would be worth two dollars, or that five grammes of standard gold would be equivalent to three dollars. And the ultimate result would be that the gramme of pure or standard gold would become the world's unit of money, superseding, by the most natural and inevitable process, all local units, or co-existing with them.

We wish these points, and others that could be named, had been more explicitly set forth; but in spite of such minor deficiencies we heartily coincide in both memorials, and trust that they will be so numerously signed as to produce a tangible effect in legislation. A copy of each memorial may be found at this office, and persons in sympathy with the objects of either are cordially invited to sign it here.

A Novel Condenser.—We notice that a M. Körting has invented and introduced a novel condenser, in which the work required to eject the condensed water is performed by its own velocity, instead of by the old-fashioned air-pump and hotwell. The condenser is of the old injector form and principle, in which the exhaust steam is admitted by various concentric cones around a stream of falling water. This disposition of parts causes the exhaust steam from any cylinder to offer a large surface to the cold water. Condensation is thereby effected, and a very considerable velocity is produced in the descending column of water. This causes a considerable vacuum behind the falling column. In order to produce the required effect, it is necessary that the falling water should have a small initial velocity. In M. Körting's arrangement the water has a velocity due to a head of three metres. The water is pumped up into a tank at that height by means of a pump attached to the engine; so that the power required to work this pump must be deducted from the effective gain of the condenser. The advantages of the apparatus are thus summed up:—

1st. Its price is not more than from an eighth to a quarter of an ordinary condenser. 2d. There is no need for any foundation, and consequently it is easily applied to existing engines or to new ones. 3d. It works without air-pump, which serves the loss of work and the inconveniences of setting up and of operation of the latter. 4th. There is nothing to regulate, and in consequence it demands no particular care from the attendant. 5th. As there are no moving parts (piston, valves, etc.), there is no wear, repairs, or interruption in work. 6th. Its application is especially advantageous to small machines, where the inconvenience and the price of an air-pump is very great.

COAL SUPPLY AND THE IRON INDUSTRY.*

By I. LOWTHIAN BELL.

From "Engineering."

The greater portion of the habitable surface of our earth is of such a temperature as to require for the comfort, and indeed for the health of the human family, the development of artificial warmth. In tropical climates this necessity is of rare occurrence, but even there the agency of fire is constantly had recourse to for the preparation of food, however rude and simple a process this may be. The absence, then, of the means of producing heat artificially, certainly in regions of moderate temperature, would practically be equivalent to unfitting them to serve as the abode of man.

Human life, it is true, is susceptible of being maintained, even in the most northern latitudes, with the assistance of a very small amount of combustible matter. In the Arctic regions, for example, where vegetation in the higher forms is entirely wanting, the fuel used is devoted exclusively to culinary work, the animal warmth of the inhabitants being maintained by the family living in a small, and consequently overcrowded apartment. As an accompaniment to this mode of life, no doubt the health of all the occupants of such dwellings must suffer from the unavoidable vitiation of the air they are breathing.

It is needless to remind this meeting that whatever might be the condition in respect to civilization of a nation, wood in the first ages of its history was the only fuel made use of, obtained quite readily from the forests which, in by far the greater majority of cases, would everywhere abound. For the purposes of agriculture and for habitations, these would be partially cleared away, but that which remained would far more than suffice for the wants of a thinly peopled district. It is nevertheless consistent with actual experience that perfectly civilized nations can, not only exist, but carry on various industrial enterprises, and yet be entirely dependent for the fuel they require on the forests, which more or less still cover the face of their respective countries. Thus, both Norway and Sweden occupy a position of some importance as iron-producing communities, yet, in both of these, charcoal is the exclusive source of the heat required in the furnaces and forges.

In neither of the nations just mentioned can we connect the importance of their position as iron manufacturers with a large production of this indispensable article of civilized life, for some individual firms are to be found in this empire who deliver to commerce as large a weight of the metal as is produced in all Norway and Sweden combined.

It is probably due to the fact that industry can thus be maintained independently of mineral fuel, which has given rise to a recent suggestion, that the day might come when nations which have partially or entirely abandoned the use of charcoal, might find themselves constrained to devote their attention once more to the growth of timber as a means of commanding temperatures of artificial production. However practicable this may be in countries where the soil is incapable of being put to other uses, it may be dismissed at once from one like our own, even were the land not required for food-producing purposes. Indeed it may be safely said that no people could long carry on large manufacturing operations where forests were to be the sole sources of the fuel required.

In illustration of this, imagine one of our modern blast furnaces placed on the edge of a forest. Such is the quantity of combustible it devours, that by the end of the first year of its existence about 1,400 acres of trees would have been felled to satisfy its requirements, or a space more than 2 miles long by a mile in width. Compare this with the powers of a mine, from an ordinary seam of coal, in which 5 or 6 acres would give as much available fuel for smelting purposes as these 1,400 acres of wood.

No doubt the forest possesses a quality not to be found in the mine, for while an interval of 30 or 40 years is sufficient to reproduce its trees, a seam of coal, once robbed of its treasure, is exhausted forever. Not even this disadvantage, however, can be held as being of much account with a nation such as Great Britain. I arrive at this opinion by finding that our blast furnaces alone, which only consume

* From the Address of I. Lowthian Bell at Manchester.

about one sixth of the coal raised in this empire, would require for their use a surface of more than 20,000 square miles covered with grown and growing timber, which is nearly one-fourth of the total area of Great Britain. Independently of the impossibility of sparing such a breadth of land for such a purpose, it is evident the mere conveyance of fuel to be collected over such a wide-spreading space would render the manufacture of iron, as it does elsewhere, an undertaking of great cost and extreme difficulty.

This liability to exhaustion of our coalfields has, very properly, conferred upon the question of fuel supply in this country a great and increasing importance. To such an extent did this prevail, and rouse the national fears thereon, that measures were in contemplation for the extinction of the National Debt, which had to be paid off previously to our coal being consumed; otherwise it was justly feared that the security held by the country's creditors would be materially reduced in value by the decadence of an industry which would inevitably accompany a want of fuel.

A Royal Commission was appointed, and as a result of their labors the nation has been assured that with an increase of something like 25,000,000 tons upon our present annual demand, we have enough to serve us for 1,000 years, so that neither we nor any immediate Chancellor of the Exchequer need be under any pressing alarm as to our ability to pay our debts in full, so far as this is affected by the possession of coal.

Notwithstanding the satisfactory character of these investigations, conducted by very competent men, almost within twelve months of the completion of their work, we have coal rising to and continuing at a price, which nothing short of a prevailing and permanent famine would appear to justify. For this apprehension I firmly believe there exists no necessity. There is, no doubt, coal enough to last for many generations to come, and additional fields are being discovered, which in all probability will greatly add to the powers of production laid down by Her Majesty's Commissioners in their Blue Book, which contains at ample length the basis of their calculations. It is obvious, of course, the price of a commodity may be influenced by one or two causes; it may either rise in value from actual scarceness, or from an increased demand for its use. The recent, and even the present extraordinary high cost of coal has arisen from a combination of these two causes, but the former certainly is not in any way connected with any approach to that exhaustion of our natural powers so much dreaded a year or two ago.

Fuel forming so indispensable an item in the expense of most manufacturing processes, it is clear its cost to the consumer is a matter of first importance in placing him in a position to compete with other nations. At the same time I am very far from thinking, looking even to a future of no remote distance, that very cheap coal is not an unmixed benefit. Not only does its low price render us unmindful of waste, but the very circumstance of cheapness renders it inexpedient, because unremunerative, to make any attempt to introduce means and appliances for its economy. Within my own recollection vast quantities of small coals were supplied to the chemical and iron works on the banks of the Tyne for less than two shillings a ton, a state of things which it is needless to say afforded no margin or inducement to the manufacturer to cease being careless in its application.

One result of this profuse expenditure of fuel is, no doubt, being felt in many instances, even in our time. As a rule, the least expensive coal is the first worked, and by just as much as we have wasted our most economically-wrought mines, have we wasted the country's resources to an extent represented by the difference between these and others involving a greater cost of extraction.

Without any reference whatever to the exhaustion of our beds of coal, there are other circumstances which may seriously impede the industrial progress of a nation, and among these not the least important is the want of labor to meet the numerous requirements which a constant demand for an increasing market may entail. So long as the population of a country is in excess of this demand, no enterprise will ever fail for want of the human hands needed for its prosecution, but the moment every one is actively engaged it becomes a question of imperial importance and necessity that as few men as possible should devote their energies to an occupation which might be dispensed with under a different condition of things.

Ultimately, no doubt, as we are taught

by the laws of political economy, such a disorganized state of things as would ensue from an excessive price of coal would find its own level, but to ourselves at what cost? I have known railway bars sold at such a price as would now barely cover the price of the coal required in their manufacture. Let us suppose a country like the United States entering the market against us, as it now, with our enhanced price, is doing largely. This country possesses an extent of territory capable of furnishing the means of supporting countless bands of workmen. It has iron ore in great abundance, and known coal-fields thirty times as large as our own. If, in our case, where the existence of mineral fuel has been known at least 2,000 years, we are still discovering fresh beds of coal, we may regard North America as little likely ever to run short of the means of heating its furnaces as we stand in danger of not being able to build houses for want of stone.

From the fact of iron absorbing nearly one-third of the entire coal raised in this country, this trade would first feel the pinch, and, by the extinction of a portion of our furnaces, we would relieve the fuel required for their use, and enable it to be applied to other purposes, which could better afford to pay the enhanced price.

There are, no doubt, many disturbing causes which render the investigation of such a question as that under consideration one of extreme complexity and difficulty, but I trust enough has been said to prove that an avoidable waste of coal is a national sin, an injury to ourselves, and a great injustice to our successors.

I fear, in spite of what has been done to reduce this waste, still much more remains to be accomplished, and therefore it would be difficult to conceive a more appropriate start for a society established for the promotion of scientific industry, than an exhibition of appliances for the economical consumption of coal. It is appropriate, because economy in consumption is, as we have seen, of national importance, and because no subject which engages the consumer's attention is more dependent on science for a proper appreciation of the laws which regulate combustion, and for a knowledge of the effects produced by burning fuel.

Of the 120,000,000 tons of coal raised annually in this kingdom about 20,000,000 are now used in the manufacture of crude pig iron. It is a branch of our national industry which furnishes a ready and striking example of the danger which attends the pursuit of similar undertakings without that assistance which science is alone capable of affording. It will be within the knowledge of many of this meeting that, although the earliest record we possess indicates the existence of iron to have been well known in the remotest ages, it was exclusively in its malleable form that this substance was known to the human race. It was obtained in this condition by means of rude furnaces, 2 ft. or 3 ft. high, and, in the hope, probably, of saving fuel, these pigmy structures were increased in height until the change of conditions permitted a portion of the carbon of the charcoal to unite with the metal and form cast iron. The experience gathered from this course of procedure gave rise, about the sixteenth century, to the so-called blast furnace. In the earlier forms of this well-known apparatus, by far the greater portion of heat generated in the hearth would be carried away by the great volume of highly-heated gases arising from the combustion of the fuel. Our ancestors would doubtless find that by increasing the height of the column of matter they were operating on, a part of the escaping heat would be intercepted, and combustible in consequence would be economized. Successive additions led to iron furnaces being built 40 ft. or 50 ft. in height, and so they were left until within the last dozen years. Now had any ironmaster, previously to the introduction of the hot blast in 1828, ascertained by chemical analysis and observation the composition and temperature of the gases escaping from one of his blast furnaces, he would have learned that, independently of the imperfect combustion he was effecting, there existed in the form of sensible heat in these gases a value far more than that due to half the fuel he was burning.

A knowledge of this fact was either wanting, or its significance was unheeded, and notwithstanding the experience gained by gradual additions to the dimensions of our furnaces, it is a little remarkable that it is only within the last ten years that we learned that a simple addition to their height enabled us to save fully one-half the fuel formerly required.

In the mean time, *i. e.*, about forty-five years ago, it occurred to the mind of Neil-

son to heat the air before it was propelled into the furnace. This was accompanied by such an enormous saving of fuel that all kinds of explanations were given to account for the apparently miraculous effects of the hot blast. The true one, as I believe, is that by reducing the volume of gaseous matter flowing through the contents of the furnace, more time is given for it to raise the temperature of the materials and to effect the reduction of the ore under treatment. The absence of this knowledge has led ironmasters in the meantime to incur large outlay in the construction of costly apparatus for heating air, while the same effects might in many cases have been just as easily attained by simply adding 20 ft. to the height of the furnace.

These remarks might appear to indicate an opinion that the application of hot blast in the manufacture of pig iron may now be dispensed with. This is not my meaning, for by the use of the gases formerly burnt for no useful purpose at the throat of the blast furnace, the air used in the process is heated and adds to the general economy of the process, although in a much less striking degree than happened at the time Neilson made his discovery.

As the most prominent instrument which has placed this country to avail itself of its natural advantages, we should have unhesitatingly to point to the steam engine. By means of this wonderful invention you were informed by your noble President, in his inaugural address, that the inhabitants of these small islands were doing the world's work equal to the producing power of one-half the entire population of the globe we live upon. Now the steam engine, after all, is a mere contrivance to apply through the instrumentality of water the motive power of heat stored up, in our case, in the forests of bygone ages. Heat is now considered a form of motion, the two words being convertible terms; but of this I need scarcely remind a Manchester audience, for among the distinguished philosophers who have labored in this most interesting and important field of natural science, there is not to be found a more illustrious name than that of your fellow-citizen, Dr. Joule, to whose remarkable labors we are indebted for the knowledge of how much heat, and therefore how much fuel, is required to call into operation any given amount of motion or power.

The acquaintance of natural laws thus placed at our disposal by the persevering patience of this distinguished engineer, informs us of someting which cannot fail to be somewhat distressing to our national pride, for by its means we learn that our best steam engines only afford 10 per cent., and very many under 5 per cent. of the power the fuel they consume is capable of producing.

The non-manufacturing portion of the community on hearing of the misdeeds of workers in iron and spinners of cotton may possibly congratulate themselves on being exempt from this wilful and wicked waste of their country's wealth. As in many parallel cases, no praise could be less well deserved, for if a nation has to be held responsible for national sin, no purpose to which fuel is applied will have more to answer for than the domestic fireplaces of these islands.

Let us imagine four persons, burning four candles, to be placed in an ordinary apartment, say, 20 ft. long, 15 ft. wide, and 12 ft. high, and, therefore, containing 3,600 cubic ft. According to data given by your townsman, Dr. Angus Smith, were the air of such an apartment never changed, in two hours its atmosphere would contain .317, or rather more than a quarter per cent. of carbonic acid, produced by the breathing of its occupants, and by the combustion of the candles. To avoid the unwholesome pollution which would ensue from not changing the atmosphere, suppose the entire contents of the apartment had to be renewed five times in every hour, and that, as an extreme case, this quantity of air, viz., 18,000 cubic ft. had to be raised in temperature 50 deg. Fahr. by means of artificial warmth. This ought to be effected with an expenditure of about 1 lb. of coal per hour, against which quantity I would ask any householder to contrast the figures he will find in his coal merchant's bills. Such a comparison would prove beyond all question that of the 20,000,000 tons of the annual produce of our collieries, used for domestic purposes, a mere fraction is beneficially utilized.

Your President, Lord Derby, in his inaugural address, suggested an inquiry into the cost of the cloud of smoke which constantly hangs over Manchester. Its solution would not be an easy matter; but I am sorry to have arrived at the conclusion, that viewed as a money question to the offenders it is a less costly one than many

people appear to imagine. Of the carbon contained in coal about 20 per cent. exists in the volatile form, and it is to the imperfect combustion of this portion alone that smoke is due. It is very difficult, indeed impossible, to give even an approximation to the average amount of defective oxidation or combustion of this volatile carbon in a large town like Manchester; but speaking from the result of my own observations I deem it improbable that even so much as one-fourth of its weight escapes combustion. If so, then the loss from smoke is equivalent to something under 5 per cent. of the total weight of coal consumed.

The cost of smoke to the producer has unfortunately not hitherto been sufficient to induce him to guard with the necessary care against its occurrence, and the loss falls on society at large, which is made to pay for the visitation, in the presence of dirt-defaced buildings, and a ruined landscape. Smoke is unquestionably one of the preventable evils we have in this country to endure, and it is one of such a magnitude as to justify public attention being directed to its amelioration.

A remarkable instance of the waste of fuel, and nuisance arising from smoke, is to be found in the manufacture of coke. This operation consists in expelling the volatile constituents of coal by means of heat, which is performed in a vaulted chamber, formerly constructed with a simple opening at the top, the latter not more than 10 ft. above the level of the ground. At the present moment there is produced annually in the county of Durham alone, something like 3,000,000 tons of this charred coal, which means that out of ovens of the old form, and still frequently in actual use, the smoke from upwards of 5,250,000 tons of coal, and containing probably 20,000 tons of sulphur, in the form of acid vapors, would be distributed over the face of the country, vomited from thousands of low chimneys only 10 ft. high. This barbarous state of things is being rapidly amended in the district alluded to, but not without a struggle, and before miles upon miles of land have been changed from landscapes of great beauty to a blackened wilderness. So far as the nuisance from imperfectly-consumed gas was concerned, the remedy was simple. All that was needed was a flue and chimney of sufficient altitude to dilute the vapors with atmospheric air before they reached the ground, and yet this was resisted ostensibly because it was alleged it affected the process, but I fear, in reality, because the coke burner objected to the expense of construction. As regards waste of fuel, I estimate that upon the 3,000,000 tons of coke produced there is a loss of heat fully equal to 2,000,000 of tons of coal, a loss which, in most cases, is going on at the present day.

It frequently happens the manufacturer has to submit to what, so far as his own special operation is concerned, is an unavoidable loss of heat, arising from conditions of its evolution and the temperature at which it is escaping; but this is not the case with the coke burner. The ovens are almost invariably at the colliery, where large quantities of steam are required for raising the coal from the pit, and freeing, the mine from water. For this the waste heat of the coking process is amply intense, and speaking from my own experience, I may say that in collieries with which I am connected, there has been a saving of from 15,000 to 20,000 tons of coal per annum by connecting the engine boilers with the coke ovens.

I have thus endeavored in the very short time placed at my disposal by the Council of this Society, to select a few instances in attestation of the propriety of calling by means of an exhibition public attention to the study of an economical consumption of fuel. The researches of the mathematician have placed within the reach of every one rules for dealing with space and numbers. Your townsman, John Dalton, a name honored wherever science is revered, bequeathed to mankind an everlasting legacy in the "Atomic Chemical Theory." The mechanician and engineer cannot move a step without mathematical knowledge, and the manufacturing chemist, ignorant of atomic weights, is as a mariner on the wide ocean without a compass.

In more modern days chemists and physicists, led on by the charm which accompanies all investigation into the secrets of nature, have made us acquainted with the laws regulating combustion, the heat produced by coal in its different degrees of oxidation, the exact nature of the chemical action of many of our processes, along with the quantity of heat required for its accomplishment.

Among the latest discoveries is that which enables an engineer to state correctly the

maximum moving force evolved by burning a pound of coal.

Shall it be said that they who consume coal, who are making inroads, slow, it is true, but sure, into the stock of a material upon which our commercial prosperity is founded, shall pursue their avocations as if no such knowledge as that to which I have alluded lay ready for its proper application.

To this inquiry I trust the labors of the Council of the Society for the Promotion of Scientific Industry, will afford the assurance of a direct negative.

THE HORSE-POWER OF BOILERS.

From "The Engineer."

We are happy to state that there is some ground for believing that the vague term "nominal horse-power," as applied to steam engines, is falling into disuse. The action of the Admiralty has no doubt tended to this end. For some time past, although the nominal power of engines is given in our naval returns and reports, the figures have been invariably accompanied by those which express the actual power of the engines as derived from indicator diagrams taken during the official trials of a ship. The good example thus set is being followed by many engineers; and it is not unusual nowadays for a maker to state that he cares nothing about nominal power, but that his engines will indicate such and such a power with a given pressure of steam. This is as it should be, and we venture to hope that the time is not distant when engineers will refuse to buy and sell engines by the nominal horse-power, preferring instead to give the actual dimensions of an engine in cubic capacity of cylinder per minute. We are not aware that this method of estimating horse-power has ever before been proposed. Engineers are, however, drifting towards it; and many engines are now sold by the diameter of piston, and speed in feet per minute. It is obvious, however, that the expression we have suggested is far the simplest that can be adopted, as it combines at once the velocity of piston and its diameter. Of course it may be urged that the terms are still indefinite, because the power will depend on the boiler pressure and the grade of expansion adopted. As it happens, however, that pressures and grades of expansion do not vary within very wide limits, it would be easy to adopt a standard which would suffice for all commercial purposes. For example, a very common type of engine, such as is used in our cotton factories and mills, works with a boiler pressure of 60 lbs. above the atmosphere, the cut-off taking place at one-fifth of the stroke. This represents a very good class of engine, and no difficulty would be experienced in assuming the presence of these conditions, and then expressing the power of the engine, as we have said, in terms of the cubic feet swept through by the piston per minute. Thus, if the piston of one engine sweeps through twice as much capacity as another in a minute, it is of double the power; and no account whatever need be taken of the length of stroke, diameter, or number of revolutions. We commend the idea to the attention of our readers.

Although, however, there is some prospect of a change for the better in estimating the power of engines for trade purposes, we regret that in the matter of boiler power the prospect is not so satisfactory. If questions connected with the nominal horse power of engines are unsettled and vague, those referring to the power of boilers are simply in a state of chaos. At the present moment there is absolutely no received rule for estimating the power of a boiler; that is to say, no rule generally recognized by the trade. As regards Cornish boilers, for example, some makers give 1 ft. in length for each nominal horse power, regardless of any other conditions; and thus, whether a boiler is 5 ft. in diameter or 7 ft., if it is 30 ft. long, it is a 30-horse power boiler, and so on. Double-flued Lancashire boilers are rated a little higher, 9 in. length of boiler representing a horse power. Nothing can be more vague, perhaps than this. If we turn to marine boilers, we find some makers estimating their power entirely by the grate surface; but while one maker divides his grate area by .8 and calls the result the horse power, another uses .75, and another uses .5. Thus, a boiler with 100 sq. ft. of grate surface may be called 125, 133, or 200 horse power. Others, again, neglect

grate altogether and go by heating surface; and anything between 12 ft. and 25 ft. is said by different makers to represent a horse power. As for portable engines, the power of the boiler is always expressed in terms of the diameter of the cylinder! Nothing would be more difficult than to settle a dispute between the seller and buyer of a boiler concerning its horse power, if reliance were placed solely on the practice of the trade. To all intents and purposes there is no trade practice in the matter of more than the most local and limited application. It is hardly necessary to say that this position of affairs is and has been unsatisfactory; but if it was bad before, it is rendered much worse by the introduction of new boilers of the sectional type, to which not even the semblance of a trade rule can be made to apply.

The evil has been so much felt in the United States, that as far back as 1870 the Franklin Institute, a well-known scientific body, holding their meetings in Philadelphia, and taking a position somewhat between the Royal Society and the Institution of Civil Engineers in this country, appointed a committee to investigate the whole matter, and endeavor to arrive at some definite conclusion as to what should be deemed to represent a boiler horse power. The committee sent in one report on June 21, 1871, a second report on June 18, 1872, and two additional reports on November 19, 1873. These several reports have brought the labors of the committee to a conclusion, and the committee has been dissolved. After a most elaborate investigation, and an enormous correspondence with engineers all over the world, the result arrived at by the committee is that Watt's old rule, with limitations, better than any other defines the horse power of a boiler. This rule runs, as many of our readers, though probably not all, are aware, thus: 1 sq. ft. of grate surface, 1 square yard of heating surface, and half a square yard of water surface, represent a horse power; and these dimensions will suffice to evaporate 1 cubic foot of water per hour. The committee saw in a moment that under the existing conditions of boiler engineering it would be impossible to apply this rule in its integrity, because, for example, in most modern boilers much more than 9 sq. ft. of surface are allowed to each foot of grate; so it has been finally settled by the committee that the evaporation of a cubic foot of water per hour represents a horse power, and that, while on the one hand a purchaser of a 20-horse power boiler has a right to receive a boiler which will evaporate 20 cubic ft. of water per hour, so, on the other hand, a maker has fulfilled his obligations if that which he sells as a 20-horse power boiler will evaporate 20 cubic ft. of water per hour. The committee add that after all it is utterly impossible to lay down any satisfactory, or even approximately satisfactory, standard for estimating the power of a boiler, and they go on to say that, "in view of variations of capacity of the same boiler under varied conditions, the discontinuance of the term horse-power, as descriptive of the size and capacity of the boiler, would appear to be proper; and it is suggested, as preferable, that purchasers and makers should, instead, describe fully and in accurate terms the evaporative capacity of boilers proposed, and the conditions under which they are to be worked and tested, or to specify the indicated horse power to be developed in an engine under fully and exactly stipulated conditions of speed, pressure, economy and grade of expansion." We cannot help regarding this as being in one sense a very lame and impotent conclusion; perhaps unavoidable, certainly unsatisfactory. It is, of course, highly desirable that in purchasing boilers strict stipulations should be laid down as to the quantity of steam which they must supply in pounds per minute. But such a stipulation does not at all meet the real difficulty of the case. To the great majority of boiler buyers, weights of steam and water pressures, temperatures, and all such questions are so much Sanscrit. They buy a boiler where they best can—an immense trade, for example, is done in second-hand boilers—and the only means they have of explaining what they want is to state the horse-power of the boiler they require. A great many boiler makers and boiler sellers, brokers, auctioners, and others, know nothing about the steam-generating powers of the boiler they sell; and in such cases the recommendations of the Franklin Institute Committee would be absolutely a dead letter. Something equivalent to the phrase "nominal horse power" is essentially necessary in the boiler trade; and if some definite idea were attached to the words, and accepted generally throughout Great Britain, all that is really required would be done. It has been proved that it is quite out of the question to attempt to lay down

any rule applicable to all classes and varieties of boilers; but it is not difficult to divide boilers into groups, and practice is so far identical as regards each group, that it is quite possible to establish a satisfactory standard of power for each.

We suggest, then, the adoption of something like the following scheme as a solution of the difficulty:—Let all boilers be divided into four classes or groups. The first will include Cornish, double-flued, and plain cylindrical generators; the second will include the "box" type of marine boiler; the third will be the cylindrical high-pressure marine boiler; and the fourth will be the portable boiler. Locomotives we exclude altogether, as those engines are never bought and sold by the horse-power. In the first group let 10 sq. ft. of heating surface be held to represent 1-horse power. This is very nearly Watt's rule, but it supplies a more convenient coefficient than Watt's, as it is only necessary to ascertain the whole heating surface, no matter how obtained—by Galloway tubes, for example—and to cut off the last figure; the remainder shows the commercial horse-power. As regards the second group, low-pressure marine boilers, let 20 sq. ft. of heating surface be taken to represent 1-horse power; this is closely in accordance with trade practice at present. There is more difficulty in settling the power of high-pressure marine boilers. These are almost invariably deficient in grate surface, and the tube surface is much larger in them as a rule, as compared with the grate area, than it is in "box" boilers. The grate area is, however, after all, too important a factor to leave out altogether, and therefore it will be proper to bear in mind that each foot of surface is not so efficient in the high-pressure as in the low-pressure boiler, although these high-pressure boilers are the more economical of the two. All things considered, we believe it will be fair to take 30 sq. ft. of high-pressure cylindrical marine boiler as representing a commercial horse power. As to the last group, portable engine boilers, this may be made to include as well a large number of stationary boilers which are of the portable engine type, with large tubes. To this group we should assign 15 sq. ft. of surface as representing a horse power.

We do not suppose that the standards we have thus laid down will meet the wishes of every engineer, and we wish it to be understood that we do not put them forward as being more than approximately the best that can be adopted. We believe, indeed, that the entire subject ought to be discussed fully by engineers and boiler makers in our correspondence columns, and thus an expression of opinion might be elicited which would go far to settle the question. Of the importance of the points at issue there can be no dispute; and we feel assured that it requires but a little exertion and discussion on the part of boiler makers to place the purchase and sale of steam generators on a satisfactory footing. It is not probable that any decision which may be arrived at will give universal satisfaction. But we rest convinced that if a few eminent firms would agree among themselves as to what the words "nominal boiler horse power" mean, others would follow suit, and, perforce, accept a decision which would quickly be regarded as legally binding, because representing trade practice of the highest class.

OUR KNOWLEDGE OF HYDRAULICS.

From "The Builder."

A knowledge of the science of hydraulics is one of the most difficult and important of all the acquisitions of the engineer. The subject is one of which the delicacy is equal to the importance. It lends itself, on the one hand, to the most profound mathematical investigation; while, on the other hand, it often presses for the most rough-and-ready solution in daily practice. It is the key of sanitary engineering. The supply and flow of our rivers, the amount of rain-fall, and (what is of far more moment than the actual descent) the quantity of that fall that betakes itself to the ascertainable water-way of river channels, are matters of vital importance to be known and understood.

Let none of our readers think that we are speaking on theoretic grounds alone. It is from no wish to insist on the mathematical form of the problem, and to undervalue the importance of the practical part, that

we now write. We will mention one fact, which is more eloquent than any argument we can frame, in stating that we have yet our A, B, C to learn as to the hydraulic system of this country. The quantity of water that is annually drawn from the Thames by the five great water companies that supply London from that source, is pretty accurately known. Is it credible that there should be a doubt, not in the minds of those unacquainted with engineering subjects, but in the minds of those who write to instruct the public upon them, or who offer evidence before commissions of inquiry, as to the proportion of the total volume of the river borne by the quantity of water thus abstracted? Yet such is the case, and that to an extent that is perfectly wild. It might be tedious to give all the details which lie before us as we write; but the upshot is, that while the eighty millions of tons of water that are thus abstracted form, according to the Report of the Royal Commission of 1869, only about 1-25th part of all that falls over Teddington weir, they amount, according to another statement, to fully an eighth part of the quantity that so falls when the Thames is at its lowest. So prodigious a discrepancy is enough to show that the subject of river hydraulics is not one as to which the engineers of Great Britain have any great reason to feel satisfied with their acquaintance.

In fact, we have far better opportunities in this country for studying tidal phenomena than for mastering those of rivers. Our coasts are swept by tides of almost every variety known to observation. About Yarmouth, and the eastern part of Norfolk, they are so feeble as to some extent to resemble those of the Mediterranean. Yet in the estuary of the Thames they attain a considerable height. Again, in the Wey, at Chepstow, occurs a tide higher than is known to rise on any shore whatever, except it be that of the Bay of Fundy. From that formidable and destructive phenomenon which is known as the surf, and which, on the Madras coast, rushing up in a single and unexpected wave from the sea, inflicts such sudden damage, we are for the most part happily free. It is within our knowledge that, now some years ago, when tenders were asked for for the construction of an iron pier on the Madras coast, it was required by the specification that three engineers, each competent, in case of need, to take charge of the erection, should come out together with the ironwork. The main reason for that unusual demand was said to be the risk, not so much of the climate, as of the carrying off the directing officer by the surf. But even in this aspect the shores of Great Britain are not without their occasional phenomena of magnitude. Although of rare occurrence, yet one of the most striking of estuary movements is sometimes to be observed in the Severn. When south-westerly winds coincide with equinoctial spring tides, a *flôt*, or bore, such as that which occurs on the Seine, is visible below Gloucester, on the Severn. And the stone pier that runs out near the castle cliff at Scarborough was swept, a few years ago, by an unexpected wave from the north, that carried off a gentleman, whose death produced much sensation at the time.

The great points which are of value for the acquisition of positive knowledge as to river phenomena, are less ascertainable on our island. For, although we are accustomed to regard the Thames, Severn, and other sister streams as large rivers, such is not their position in regard to the river systems of the world. The area of our island, if its whole water-shed were emptied by one large funnel, is small compared with the collecting grounds of some of the vast rivers of the New World; to say nothing of that which keeps up the African marvel, the perennial flow of the Nile; while at the same time supplying the no less mighty stream of the Congo. Over the smaller area, again, the rainfall is insignificant, compared with that which deluges the Equatorial mountains. At one spot, indeed, which is known by the quaint name of Styehead Pass, a register of rainfall gives an annual depth that is almost tropical. But our physical maps divide the surface of the country into districts receiving from 25 in. to 45 in. of annual rainfall. Of this comparatively small amount of water, which runs by three versants to the sea, and which thus nowhere accumulates in one river outlet of a length of more than some 200 miles, the proportion which actually thus discharges itself is, at this moment, unmeasured and unknown.

Great changes of condition are among the elements of physical observation which are the most precious to the observer. But no less important are the phenomena of permanence and of durability. There is yet another element which, in hydraulics, is of

extreme importance, and that is magnitude. The volume of a river is a subject of extreme importance. From an accurate study of a really great river it is possible that facts may be ascertained, which will throw light on obscure phenomena in the behavior of smaller rivers. To reverse the method is less satisfactory. And when, as is but too much the case, we commence the study of hydraulics on yet smaller proportions; when from the flow of water through pipes, or narrow artificial channels, we construct formulæ, which we afterwards apply to the movement of great masses of water, we follow an absolutely non-scientific method. Our present theories as to river hydraulics are tentative and empirical, to a degree that greatly impairs their value.

Our absence of thoroughly sound knowledge on the subject of river hydraulics is unfortunately illustrated by the opposition which is often raised to the reclamation of low-lying land from tidal waters. On the banks of the Forth, the Tay, and the Clyde, many hundreds of valuable acres have lately been added to the area of Scotland by embankments. The drainage of thousands more has thus been rendered practicable. The great obstacle to the extension of this truly national and patriotic work, has been the fear of the vague and undefined rights of the Crown to the foreshore. But this legal difficulty would, there is good reason to suppose, have been removed by this time, but for the fallacious arguments brought forward, to the effect that the channels of the river would be silted up if the funnel-shape of its mouth were interfered with. The very reverse is the outcome of experience. Still, we have no man, and no work, of sufficiently eminent authority, to lay down, on this subject, the law, which is not that of Parliament, but that of nature.

We have repeatedly called attention, in these columns, to the general problem of the right distribution of the most precious gift of Providence, next to the light of the blessed sun itself, to this country,—an abundant and neglected rainfall. Very lately a writer, dating from beyond the Forth, has been attacking in detail that which we have attacked in mass. The valley of the Blackwater is the spot to which attention is thus called, by one who is acquainted with its nature and condition. Twenty thousand acres in that valley, which are now worth about 15s. an acre of rent, would be worth £3 per acre if drained. As it is, one half of this area is submerged by every flood; and the other half has the water so dammed back upon it that all the ditches are stagnant during winter, and the herbage is all sour accordingly. During the summer, this land will scarcely carry cattle; and the hay made from it is only fit for half-starved, hungry beasts; while the inhabitants live in cottages where the water is often level with the floor.

For some forty miles above its junction with the Thames, the valley of the Kennet is liable to very similar remarks. Reeds and rushes grow, owing to the barbarous method of flooding, or rather swamping, the undrained meadow lands, where the richest grass would repay ordinary care. The waste of productive power in what might be land of extraordinary fertility, entirely independent of drainage from a season of drought, is positively lamentable. The whole cost of deepening and straightening the river, in the case of the Blackwater, it is estimated, would be recouped by the increased production within five years. We cannot doubt that the same would be the case with regard to the valley of the Kennet. For men who wish to make money, not by wild speculation, but by the profits of assured industry, invested on English soil, these valleys offer the means with absolute certitude.

We have given an instance, in a variation of more than 200 per cent., in professional estimates of the volume of the Thames, of the backward state of our practical knowledge of hydraulics. If we look at the rules and formulæ, as given by our best text-books, we shall see that they do not advance the student beyond guess work. "To find the volume of flow of a stream," we are told to "multiply the mean velocity by the sectional area." That, of course, is irreproachable. But how to find the mean velocity? That question is one that demands a series of well-connected and perfectly-performed experiments; experiments that can only be satisfactorily carried out by special instruments, and with the utmost care. But so far from this important truth being indicated in our text-books, we can there only find theoretical rules as to the "relation between head and velocity." This is expressed in a formula, which we suppose that we may regard as the basis of our actual river engineering. We find no ref-

erence to observation in the formula.* The force of gravity expressed by the head of water, is all that is brought forward. When the "factor of resistance" is introduced into the equation, the same purely theoretical mode of treatment is still continued. But this is not the worst. We find positively erroneous statements added. We have a rule, thus conceived, "In a stream like a river channel, the ratio of the mean velocity to the greatest velocity (which occurs at the middle of the stream) is nearly equal to the greatest velocity plus 7.71 ft. per second, divided by the greatest velocity plus 10.28 ft. per second." Now it is not only the empirical and utterly unscientific vagueness of this statement which we condemn. The few words within the parenthesis contain just one of those mischievous assumptions which are the parents and propagators of error. Nothing can be more wide of the mark. The velocity may be greater at the centre of the stream than elsewhere. But, on the other hand, it may not. The actual fact is, that the inclination of the surface of a river being given, its velocity is a function of its depth. So far as we are aware, we shall exhaust all our English text-books on the subject without finding this primary element of calculation anywhere distinctly intimated.

We are indebted to a member of the Institute of Civil Engineers of Vienna, Mr. J. J. Révy, for a great amount of practical light on a subject of so much interest to the sanitary and to the agricultural interests of this country. It is not as a matter of theory that Mr. Révy criticises our hydraulic formulæ. Nothing can be more modest; but at the same time nothing can be more thorough, than are the observations of this very careful engineer. It seems that Mr. Révy has been employed by the Government of the Argentine Republic to report on the estuary of the Plata, and the gigantic rivers which pour into it. Of these, the mother stream, the Parana, is, with the exception of the Amazon, the largest in the world. In 24 hours it sends down to the sea a volume of water equal to that discharged by the Thames (as at present estimated) during an entire year. It soon became evident that theoretic formulæ were absolutely nowhere in presence of these circulating seas of water. No basis of calculation was to be arrived at from estimates of velocity due to head. Nay, more, it became apparent that it was no simple matter to ascertain what that head actually was. We are accustomed to place considerable reliance on the spirit-level. With a good instrument, in good repair and adjustment, a calm day, an experienced and careful observer, and the rigid use of equi-distant back and fore sets, considerable accuracy may be thus attained. We should say, as far as our own practice bears upon the subject, that a level thus obtained may be relied on to about three-hundredths of a foot per mile. That would be considered a fair check. In setting out masonry by the spririt-level, perhaps a greater degree of accuracy may be attained; but the process is slow and tedious. We can remember an instance in the case of the setting out of the retaining walls betwen Camden-town and Euston-square, on the line of what was then called the London & Birmingham Railway, in which, although unusual care was taken, and the levels were read on iron wedges driven into the joints of the brickwork, day after day they would come three-hundredths of a foot wrong! The fact was extremely perplexing. Every endeavor was made by careful adjustment of instrument, and laborious detail of observation, to detect the source of error; but day after day it recurred. At last it caught the attention that the error was always of the same amount, and always in the same direction. This led to a renewed investigation. The result of this was, that the error was not cumulative. Although it recurred in the work every day, it did not augment. This led to the running of a new series of levels along the plinths of all the pilasters that were completed. The fall was exact in every instance. At last, by reference to a bench mark fixed for the purpose, it became evident whence the difficulty arose. It was due to nothing but the expansion of the concrete on which the wall was built! The levels were always given at the same period of the growth of the wall; that is to say, on its arrival at the plinth. The same degrees of expansion in equal thicknesses of concrete had thus always taken place. This was, as it turned out, at once a beautiful proof of accuracy of work, and a valuable note as to the behavior of concrete. But it is an instance of the mode in which, with all the appliances of modern civilization, we may approach the limit of instrumental accuracy

* The formulæ are $h = \frac{v^2}{64}$ and $v = 8.025\sqrt{h}$.

in the use of the spirit-level. Over long marshy districts, jungle, swamp, or fen country, such as we find in Norfolk, the level becomes almost useless. We do far better to trust to a natural water-level, if this is shown, by the absence of current, to exist, than to rely on the use of the spirit-level, even in many parts of England. By the side of the vast rivers of America, or of Africa, such levelling is altogether out of the question.

We have spoken of three-hundredths of a foot per mile as being as fair an approach to accuracy as we can expect under ordinary circumstances. In our fen districts the minimum fall allowed for the water-channels is 4 in. per mile. The wind will stop the flow of water through the dykes, if propelled by a less head than that. The constant service of windmills, pumping day and night, and the entire system of polders, dykes, sluices, and outfall, are calculated on that gradient. Its ascertainment is, as we see, within the limit of instrumental accuracy.

Now the surface inclination of the La Plata River happens, by a remarkable coincidence, to fall within a very minute fraction in that very limit of instrumental accuracy. Three-hundredths of a foot is the same thing as thirty-six-hundredths of an inch. The surface inclination of the La Plata was ascertained by Mr. Révy to vary from .342 to .444 in. per mile, and with a gradient that in our fen districts would not overcome the opposing force of a moderate wind, the mighty volume of that great river has a surface velocity of more than 100 ft. per minute.

Into the further investigation of this great problem our limits will not allow us now to enter. But we hope that we have said enough to call the attention of all those who take interest in hydraulic knowledge to the fact, that a problem exists, and that its solution, if attained, is not to be found in our text-books, or expounded by our professors. It is no vagary of nature that impels the mighty stream of the Plata down an incline almost imperceptible to our instruments, and which our fen-draining engineers might afford to neglect. In fact, they might neglect it with safety. The cause of the apparent anomaly lies in the great depth of the American river,—a depth of 24 ft. at the section observed. To this depth is due the velocity of the current, and the constant displacement of an enormous mass of water under the solicitation of a minute gravitating force that would prove inadequate to overcome resistance in a shallower channel.

We cannot give, in a few words, a more distinct proof of the importance of regarding depth of channel as a function of the velocity of rivers; and the fact that this function is entirely disregarded by our formulæ may perhaps account for the fact, that one hydraulic authority (as things go at present) tells us that the flow of the Thames is considerably more than double of that at which it is stated by another engineer.

PUBLIC WORKS IN INDIA.

From "The Building News."

The Food Crisis in British India has revived the question of Public Works in that region; but a great deal of misapprehension appears to exist upon the point. These undertakings are not to be regarded as pretexts for giving employment to thousands who might otherwise be without wages; they are intended to make the country what it should be—fertile, available for all purposes of commerce, and open to the genius of modern industry. Anciently, the wild splendor of the Delhi dynasty, and even preceding them, the Hindoo monarchs engaged myriads of cultured craftsmen in erecting tombs which were literally palaces of the dead, and left such memorials as few other ages or nations can equal; yet these were, generally, the monuments of a foreign art, and little more than the drudgery of enterprise was left to the native race. Recently, however, a great change has occurred. The toil and skill once devoted only to tanks and temples, are given to constructions more useful and more beneficial to the land. In British India, perhaps more than in any other territory of the globe, China excepted, the fertility of the soil depends upon the adroitness of the husbandman; even this, without the help of the engineer, is comparatively useless; for where is the reason of growing crops amid which a spear-bearing horseman may

ride without being perceived, unless there exist means of transporting the surplus produce by railroad, river, or canal? India wants railways, canals, the improvement of rivers, bridges, aqueducts, and highways, which are being, as a fact, very slowly supplied to her. No doubt, a large extension has taken place; there is a line direct from Madras to Malabar; there is another, with breaks, however, at the ghauts, from Bombay to Bhosal; and, taken altogether, there may be 5,000 miles in working order. Still, these additions, chiefly military in their objects, do not meet the practical wants of that enormous population, principally resident in villages. One grand necessity is of roads, along which wheeled carts can conveniently travel. Many tramways have been constructed, against which a majority of the people have hitherto exhibited a prejudice; yet this feeling, it may be hoped, will in the course of time, be overcome. There are many districts, however, in which the mechanical difficulty of making even a passable road seems next to insurmountable, if we are to judge from the reports of the India Office. After railways and common roads, the canals and the rivers follow, though more as main arteries than as means of domestic intercommunication. A system of navigable canals is of the utmost importance, both as regards the inland traffic, and as contributing to the irrigation of a land so frequently desolated by droughts. During the last great famine in Bengal, the Ganges Canal brought grain, in myriads of tons, to the upper provinces. It covered the land with plenty, and yet it has never paid a farthing of interest upon the original cost; it fed a million and a half of people, without encouraging either Government or any union of speculators to attempt a second similar enterprise. Still, this is not true of all the Irrigation Works in India; those in the Cauvery and Coleroon districts, for example, have more than doubled the value of the grounds they water, and which famine, since their completion, has never visited. In the basin of the Godavery, again, Colonel Arthur Cotton reclaimed from sand and thirst, by a magnificent series of Public Works, 1,200,000 acres of formerly worthless but now profitable soil. These facts should have an interest for the practical classes of the public, in all countries. Colonel Cotton built a "bar," which turned the current in a full volume over the arid neighborhood, and converted the desert into a garden. So at Kistnah; so returning for a moment to facilities of intercommunication with the Grand Trunk-road from Calcutta to Peshawur, upwards of a thousand miles in length, and with that unique bridge across the Godavery where it is most dangerous, and most liable to change its course. That river, for many years, checked the benevolent ambition of Indian governors-general and engineers. It wanted clearance in some places and obstructions in others; it required a periodical storage of waters, a supplement of canals, a succession of dams and then of still-water pools, the blasting away of huge rocks in midstream, wing-walls, arm-cuts, groins, and artificial banks, and the removal of shoals caused by accumulations brought down from the mountains. But nearly all this has been effected with results the most satisfactory, notwithstanding extraordinary natural obstacles. "Our quarries and sand-beds," writes the resident engineer, "are in the bed of the river," so that, in the season of floods, they were unavailable. With respect to roads and canals, we have made a surprising advance, and attention should be given to them, especially as regards the harbors upon which they open. The bridges throughout have opposed the greatest difficulties to the engineers, although the deep channels and cuttings, the incessant cross-drainage, and the steep gradients, mounted by means of a machinery peculiar to India, have been obstacles sufficiently serious. All this, however, is essential to the very existence of the population, and it has still proved inadequate under a heavy and sudden pressure. There exists in abundance what are called "wet weather," and what are called "dry weather" roads; the one during long seasons rendered impassable by dust, the other made impracticable by muddy ruts, in which a cart's wheels will disappear to the axle. Some are entirely unavailable for carriages of any description; but all are crowded with a vast and increasing traffic, either from point to point along the various routes, or converging towards the sea. The sea approaches to the hidden interior have, of late, been wonderfully improved. Thus, the new harbor of Beitkul, almost superseding that of Madras, is almost an artificial creation, although nature has sheltered it from the worst winds of that storm-beaten coast. A small breakwater, con-

suming about half a million tons of stone; a connection of masonry effected between two little islands outside, and a noble wharf obtained by merely blasting down the overshadowing rocks, have provided a secure and spacious haven of which Anglo-Indian engineers are justly proud. All this, however, was in association with the new canal system, because the natural rivers have, for the most part, inconveniently precipitous falls, and changes of current necessitating numberless shifts of the navigation, ferries, short land transports, where the streams become no better than swamps, and so forth. India, it must not be forgotten, suffers not less from an excess than from a want of water, and the grand object of her engineers is, of course, to regulate and distribute the supply. Thus, an important interest has been practically ruined by the influx of a sweet stream into the salt swamps of the celebrated Mogultoor Talook, where every particle of saline matter was of value. On the other hand, the Hindoo looks upon the neighboring tank as English farmers do upon the rain and sun of Heaven, and upon the construction of these mighty reservoirs a mighty genius has been exhibited. They are vast, deep, bottomed with the finest sand, embanked by solid masonry, furnished with admirable inlets and outlets, and protected almost as though they were sacred. No person is permitted to bathe in them, no fowl are suffered to swim upon their surface; they are intended solely and simply for the domestic water-jar and the fructification of the fields. Their drying-up or exhaustion would signify, in an exceptionally torrid season, starvation, pestilence, and the withering away of the people. It will be seen, then, of what vital necessity are public works in such a region, in which the monuments of former industry, however magnificent, are gradually wearing away. They are necessarily of considerable cost, no doubt; but with one or two exceptions which we have noticed, amply repay it, within a short period. Thus, the great Godavery Weir absorbed:—350,000 tons of stone for the rough stone-work, at 1s. a ton; 300,000 used in rubble and other masonry; 150,000 cubic yards in rubble masonry, the deepest part of the water; 45,000 of cut stone masonry, and quantities upon a similar scale for artificial islands, excavations, and wells. We have here a glimpse of the contrast of Asiatic, as compared with European work. The artisans are principally paid in food; that is, in rice, at the rate of a farthing the pound; they dig up a square yard of earth for the same remuneration; they drive a blast of gunpowder for three half-pence per each sixteen ounces; and yet their labors, though active and ingenious, have often brought small return to their employers. On one river, 80 miles from the sea, the engineers have had to break and blow through a dense ridge of primitive rock, capped with laterite, nearly 3,000 ft. high, and they had to work their way for 5 miles before the waters could have their free fall towards the ocean. Then we must remember that the country is a Delta, infinitely more intricate than that of Egypt, and bearing this in mind, the exceeding merit of the works constructed becomes apparent. The facing wall is 12 ft. high, of rubble masonry, built with hydraulic lime, having a level surface, 18 ft. wide, and a slope curving towards the down-stream. The whole rests on sand, the lower side, being supported on brick wells, filled with stones and clay. There are embankments in every direction, to change the course of the waters, when necessary; but without encumbering our columns with superfluous details, we may describe them as three locks; three head sluices to the channels; three sets of under sluices; the embankments carried across the island; the four Weirs, 48 ft. thick of masonry, with aprons of rough stone 30 yards in width; and great irrigating channels, the influence of which is as the periodical and beneficial rising and overflow of the flood in the Valley of the Nile. It has again and again been said that water is, in India, more precious than gold in Australia: it improves agriculture; it cheapens food by cheapening transit; it prevents a bad season from impoverishing another. In three ways the fluid stored up is used: for complete irrigation; for supplying deficiencies; and for the nurture of crops that are long in ripening. We must next take into account the state of the question as it affects the internal navigation of the country. This involves the great problem of the comparative value and importance of internal navigation and land communications, with special reference to India. Whether railways are to be substitutes for canals, or canals for rivers, are still moot points. The railway can never surpass the canal in cheapness, nor the canal the railway in speed.

Which, then, is the more important loss, that of time or of cost, in transit? When the determination of policy of Public Works in India comes to be made definite, these are considerations which will not be lost sight of.

BRASS.*

From the "London Mining Journal."

What is brass? It is perhaps not so easy to answer that question. I think we shall be justified in restricting the term brass to alloys of zinc and copper only. Antiquarians and collectors of coins frequently apply the term brass to what we should call bronze, or gun metal, an alloy of copper and tin, and this causes much confusion. It is curious to find more than 2,000 years ago, in the writings of Pliny, that the same confusion existed. Now, for example, we have pinchbeck metal, Dutch metal, Prince's metal, etc.; worse than all, we sometimes find different terms applied to the same kind of brass. The old term for brass was *latten*, as we find in ancient records, and the modern French name is *laiton*. Brass was known certainly 2,000 years ago, in the days of Pliny; for he tells us there was a kind of metal known as *ori chalcum*, which means mountain brass, and it is said to have been very much like gold in appearance. But I think there can be no doubt that the term refers to our brass, inasmuch as no one would mistake gun metal for gold—its color is quite different. With regard to the common properties of brass, it has many advantages over copper, it is harder, and will, therefore, better resist wear from friction. It is a very workable metal, can be cast perfectly, it is very malleable and ductile, can be rolled out, and then beaten out (at all events when it has a certain composition)—Dutch metal for instance, can be drawn out into fine wire, raised up by stamping. It is agreeable to look at, and much cheaper than copper. When I speak of ordinary brass, without any qualification, I shall mean brass which has a composition in round numbers of two parts of copper to one of zinc. I shall describe the ancient process of manufacturing brass, which has now, however, been generally abandoned, and I do not think there is one furnace, conducted on this process, now in this country, though I saw several in full working order in Birmingham about 30 years ago. The oxide of zinc was in all cases used, and this was mostly obtained by roasting calamine, or carbonate of zinc, hence the name of calamine brass. You will remember that zinc is obtained from this oxide by heating it with carbonaceous matter in a closed vessel. Now, to make zinc we should take some of this oxide, mix it well with charcoal powder, and add a quantity—in proper proportion—of granulated copper; the mixture is then put into large crucibles and heated strongly for several hours. The zinc vapor thus separated finds itself largely in contact with metallic copper throughout the mass; it continues with the copper and forms brass. The point to be attended to is not to raise the temperature so high as to melt the copper, or that metal would form a layer at the bottom of the crucible, and our object is to keep the copper as much as possible in contact with the zinc. The furnace used is very simply constructed, merely consisting of an oven-shaped building of fire-brick; there are no bars, but a plate of iron (protected with fire-clay) pierced with holes for admission of air, and other larger holes (one in the centre, and seven or eight at equal distances round the plate), in which the crucibles are set. In the top of the furnace is inserted a cast-iron collar, and over that place a cover of cast-iron, which serves as a damper to regulate the temperature; there is no chimney. There are several of these furnaces built in a row, and enclosing them all is built a large kiln, like those we see in modern glass-houses. The furnaces are built nearly on a level with the ground, but there is an underground passage to each of them for the removal of ashes, etc. When the furnace is in working order the charge is introduced into the crucibles, and they are put in their places; the fuel is introduced gradually, and worked down and between the pots, the object being to keep up a uniform temperature. After a lapse of several hours the furnace will have done

* Abstract of Dr. Percy's Lecture on Metals before Royal School of Mines.

its work. We then take out the central pot, and shake it well to get the molten metal to the bottom; it occupies but a small space compared with that occupied by the charge. Each of the other pots are taken in succession, and after shaking, the contents are emptied into the centre pot, and by this means we get at the end of the process, a crucible full of brass which is then cast into ingot moulds, which in former times were made of stone. This calamine brass had a great reputation, it was in high repute for buttons, for wire drawing, and especially for wire intended for paper-marker's gauze. I do not see why this brass should be so much better than that made from good copper and zinc in modern times, and I do not think it was. A few days ago we submitted to a vigorous analysis a specimen of this brass, which I obtained some years ago from Birmingham, and it showed—

Copper	60.67
Zinc	34.23
Lead	3.61
Tin	0.17
Iron	0.77
Nickel, cobalt	Traces
Total	99.45

The most remarkable feature is the large percentage of lead; as a rule, I may say the more free the brass is from lead the better it is. The brass is now made by adding spelter to the copper, previously heated to a certain degree. It is made on a very large scale in reverberatory furnaces, and there is some loss due to the volatilization of the zinc. Here is a simple experiment: let anyone take one of the old pennies, or a piece of copper, take a crucible, and put a small piece of spelter at the bottom, then on that some charcoal or fire-brick, then the disk of copper, and cover all with charcoal; heat strongly, but not too high; a coating of brass will be formed on the copper penetrating deeper the longer the process is continued; some of the Nuremberg brass is supposed to have been produced by a process of this kind.

Among the varieties of brass is one known as Muntz's metal, intended for sheathing ships. This metal, now so largely employed, is nothing more than brass, consisting of 38 per cent. by weight of spelter, and 62 per cent. of copper. The late Mr. Muntz took out a patent for it, and recommended the proportions of the metals to be used as 40 and 60, but it has been found that they are not the best proportions; it is better not to have so much spelter, as the metal is then not so liable to become crumbly. It can be rolled at a red heat, but if cooled down to a certain degree it is no longer capable of being rolled; cooled still lower, it again becomes malleable. Here is a curious fact about it; a patent was granted to Mr. Collins in 1821 nearly identical with that granted to Muntz; it was the same thing, recommended in nearly the same proportions for the same purposes, and stated to possess the same qualities. I do not now wish to get into any argument about patents, but I do say that while in the records of the Patent Office such a patent as that of Collins was written, although it might never have been brought into practice, still another patent, to all intents and purposes identical, ought not to have been granted. To show the varieties of composition in brass, here are the results of analyses of several specimens of commercial brass obtained for me by a friend; the percentage of copper in them being—No. 1, 59.59; No. 2, 63.22; No. 3, 91.44; No. 4, 71.2; No. 5, 64.85; No. 8, 75; No. 9, 72.64. If we take copper and zinc in inverse proportion—two of zinc to one of copper—we shall get a metal totally unlike zinc, very brittle, white, and quite valueless. Some time ago there was a question about cleaning some of the metal statues in Westminster Abbey, and I recommended it should be done with ammonia, something which would not corrode the metal. I thought the metal might be brass, but I found I was mistaken; here is the exact composition of the metal, the result of an analysis which has not yet been published—

Copper	83.3
Tin	1 52
Zinc	14.47
Lead	0.17
Iron	0 53
Sulphur, silver, gold	Traces.

It is substantially a brass rich in copper, the gold is probably derived from the gilding, the gilding being attached in the manner technically known as water gilding.

Another variety of brass is Dutch metal, which contains a very large percentage of copper; it is rolled out into thin leaf, then beaten out, so as to reduce it to somewhere about 1-32,000 of an inch. Then we have what are known as brass foils, sometimes most beautiful things; it requires a first-

rate quality of brass, containing a good deal of copper to be able to be rolled out thin. Jewellers sometimes employ them, I think I may say not unfrequently. A very short time ago a lady showed me what she thought was a very fine amethyst, but I soon saw that it was only quartz with a piece of foil at the back. And those cheap chains too which we see so commonly now, have a core consisting of brass and gold, about eight parts of brass with a gilding of a thin film of gold. They are made by machinery, and are apt to become brittle in the course of wear.

In the ordinary process of pressing or stamping brass, as in making curtain rings, you cannot raise the surface by one blow, it requires a succession of blows. This, however, would make it brittle if it were not prevented by annealing the metal from time to time. In the process of annealing it becomes coated with a black scale which can be detached by means of aquafortis. The process of "dead dipping," to obtain a dull surface, is conducted by dipping the annealed metal into aquafortis (one part of aquafortis to four of water) till the black scale rubs off easily; then after washing in water it is dipped into acid of double the strength; this acid will attack the metal and form a green layer on the surface which really consists of bubbles of gas. When it is well coated it is taken out and washed and rubbed with cold saw-dust, and without removing the adhering saw-dust is plunged into the strongest acid. It is taken out of this almost immediately, and washed in water containing cream of tartar dissolved in it, and lastly it is placed in hot saw-dust.

THE VIENNA DOME.

From "The Building News" and "The Architect."

At the general meeting of the Institute of British Architects, Mr. J. Scott Russell, F. R. S., read a highly interesting paper on the construction of the central dome of the Vienna Exhibition Building. Mr. Russell, in his prefatory remarks said, all that he, as a professional engineer, could venture to do, was to submit for consideration those engineering principles and mechanical expedients which he thought might possibly be of service to the architectural profession in those great works which they and their successors would be called upon to undertake in the architecture of the future. His own special work in connection with the Exhibition building at Vienna was the great central iron dome. He felt it his agreeable duty in laying before a meeting of the architects of England a description of this building. From the beginning of it to the end he was deeply indebted to members of their profession for kindly help and cordial co-operation. The designs were all drawn for him by Mr. John Crace, the worthy son of a father who had long before acted a distinguished part in beautifying the two palaces of our own Exhibitions. The architectural features and decorations of the dome, as now executed, were the work of M. Hasenauer, who, at an early age, had evinced high distinction, and who inherited the traditions and talents of their profession from his distinguished father. Passing to a general description of the conic dome at Vienna, Mr. Russell stated that it was, he believed, the largest vaulted roof in the world. It covered nine times the ground of the dome of St. Paul's, eight times the area of the dome of St. Peter's, and seven times the area of the dome of St. Sophia at Constantinople. It was 360 ft. in diameter, and was 1,080 ft. round. It stood on a ring of 30 columns, 36 ft. apart, all round the circumference. Within this ring of columns there was no support. The upper dome, 100 ft. in circumference, admitted light by a series of windows, 40 ft. high and 10 ft. wide, between 30 columns which carried the upper dome. The slope of the cone was 30 deg.; the length of the slope on all sides was 200 ft. The roof was formed of 360 iron plates, tapering uniformly upwards from the circumference to the apex of the cone. They were riveted like the plates of a ship, each row of plates covered 1 deg. of the circle, each bottom plate was 1 yard wide between the lines of rivets, and 1 metre wide over the lap; each of the 30 columns carried an arch and an upper gallery all round the inside. These columns were 80 ft. high. The heights of the whole, in round numbers, were: columns, 80 ft.; cones, 100 ft.; windows, 40 ft.; lantern and crown, 60 ft.;

or 280 ft. from floor to crown, besides foundations of 12 to 20 ft. This conic dome roof had no visible external wall; it was surrounded by a circular ring building which consisted of the great central nave of the longitudinal axis of the main building, carried circular-wise round the cone, and forming, as it were, a circular aisle or series of side chapels all round about it. The conic roof, therefore, as seen from the exterior, crowned the large lower buildings by which it was surrounded, and seemed merely to grow out of them, and to group them round it into one whole, of which it was the centre. The circular ring or nave or arcade was 40 ft. wide by 80 ft. high, carried on a second ring of outer slender columns, and opening out into four enclosed courts or gardens, by large semi-circular windows and many doors. This arcade extended the circle of the central building to 440 ft. diameter, and it had the great convenience of forming a workman's communication, through the entire length and breadth of the building, with all the main entrances, without disturbing the central area of the great dome.

Mr. Russell then proceeded to consider the mechanical principles of conic-dome structures. The result of the investigation of the question on which he had been occupied some 30 years was shortly this:—That a certain conic form developed the strength of the modern material of wrought iron, on a large scale of structure, so as to attain the maximun possible of strength, economy, and endurance. Having discussed at considerable length the nature of the material and the modes of applying it, he proceeded to describe the principles of construction. The first principle, he said, was unity without antagonism. Lever roofs and trussed roofs were mere modifications of ingenious waste, in the ways in which they had been generally used. The question he now submitted was whether this double waste might not be avoided. In his opinion it was avoided in his conical roof. He thought every atom of iron in that roof did its own work only. No particle did work of antagonism. In short, it was a congregation of atoms working together for the common support, without counteractive disagreement, or waste of strength, or means, or work.

The second principle was wise distribution of structural load, and especially of that heavy load of its own material on a large scale. This principle, Mr. Russell remarked, found its happiest illustration in the cone, inasmuch as that form gave an absolute maximum of sustaining-power when on a large scale. This principle ruled the structure. The third principle was co-operation of independent parts, and perhaps it was the most important of the three, viz., that in every large structure every part of the whole should be ready and able to render assistance to every other part in the performance of its duty or in the case of imminent danger. This principle, Mr. Russell said, was rarely well carried out, or recognized at its full value. In illustrating this principle he premised that the antagonist principle of independent action of parts was a tradition of both the engineering and the architectural profession. One of the most beautiful scaffoldings he ever saw was made thus for the building of a large elliptic arch:—The whole of the centring sprung from two points; to every small portion of the arch went two long beams from the two springing centres. The pair met, and they, too, sustained one stone, or one group. A second pair, starting still from the same centres, sustained a second group, and so on, till perhaps some 50 independent pairs carried the whole arch. This had the great advantage that the giving way of one pair did no harm to any other pair; it was the principle of perfect independence carried out in timber struts. In the same manner they might have seen iron bridges of the nature of iron suspension-bridges, where, instead of the single centring chain, successive points of the bridge platform were carried by pairs of ties going straight to the summits of the two piers, and thus suspending their portions independently, so that weight on one side should not affect the others.

Treating of the nature of the iron cone, Mr. Russell considered: 1st, the crushing strain, on which he remarked that an iron cone might be examined and tested in two ways. It might be exposed to pressure from within, on the hollow side, or to pressure from without, on the round side. He had never seen a formula which explained and predicted the result either way. To understand his conic roof, Mr. Russell asked his audience to fancy a ring or cylinder of wrought-iron plate homogeneously riveted together into one upright plate 200 ft. high, and 360 yards round, and 1 in. thick. It would take a height of 224 yards

to bring a weight of one ton over each inch of ring. The maximum strain possible on the lowest heaviest strained part of that ring was one ton on the square inch, say one-fifth, one-tenth, or one-twentieth of the safe or yielding, or breaking strain, therefore perfectly safe, and far within the widest practical margin. But 224 yards high for one ton of strain was far beyond his wants; he only wanted for his use less than a third part of that strain. He took a ring exactly 200 ft. high, strained therefore to less than one-third of a ton per inch; and he asked them to conceive clearly this ring resting on a smooth, flat, level base. He next asked them to follow him while he cut this cylinder in pieces—[Mr. Russell illustrated his views by diagrams on the black-board]—but leaving all the pieces in their places. He now cut the cylinder vertically into couples of triangles, one upright triangle, and an inverted triangle. He now removed all the inverted triangles, and left all the others standing upright in a ring as before, points up. He had taken away half the whole of the iron. He next inclined all these angles inwards towards each other, and they all then touched each other along the edge from heel to point. With the triangles lying in that shape and perfectly soldered in all the joints and fused by electricity, his cone was complete. The conclusion at which he arrived was, that in this state the matter of the cone was nowhere more or less strained than where it had not as yet become a cone and was the original upright cylinder; in other words, the strain on the cone was everywhere less than one-third of a ton per square inch. This was the specialty of the cone looked at as a self-sustaining roof structure, and in the matter of further economy of material he diminished the thickness of the plate uniformly towards the top, and when he had done this, only one-third of the whole material of the cylinder remained in the cone; and the maximum strain was still everywhere less than one-third of a ton to the inch.

On the subject of the tearing strain, Mr. Russell remarked it was the strain that architects most feared in roofs and domes which stretched or tore asunder the supporting walls, buttresses, arches, or ties. He closely traced the changes in the shape of the cone as it was conceived to be flattened out, from which he deduced that in correct proportion as the web narrowed did the quantity of stretch diminish. Thus, there was neither waste, defect, nor antagonism; the whole cone being in uniform tension from top to bottom, and all round. Supposing a uniform pressure of water, or a uniform fall of snow, to press down the cone top, and press out the cone base, it would meet everywhere a uniform tension of iron ring opposed to it. They thus saw that the whole cone was a series of straight-lined tapering bars, starting from a circle and meeting in a point, all of them in compression endways by their own crushing weight. They saw that at the same moment the whole cone was a series of circular hoops, increasing in thickness as in diameter, and carrying a strain proportional to the size and strength of each hoop, and increasing uniformly from top to bottom in size, in strain, in thickness, and in strength. Having treated of the subjects of the combined strains and conic skeletons, Mr. Russell remarked with regard to the practical application of the cone at Vienna, that as all structures are not perfectly adapted to all purposes, it was manifestly the duty of the architect and engineer to use each to the end it served best. Practical duty, he said, was a compromise between what one would like to do and what one had got to do. For some such aim he had been willing and ready to use a mixed structure of continuous cone and detached skeleton on large buildings. This Vienna cone was such a compromise; he claimed for it the merit of a continuous cone combined with convenience of a skeleton one.

Mr. Russell then dwelt at considerable length on the columns, walls, foundations, and accessories of the Exhibition building, which our space will not allow us to enter into; after which he proceeded to show how he brought all the strength of the cone to bear upon the columns so as to give them and itself perfect stability inde pendent of bad foundations, shaking earthquakes, and shaking hurricanes. This cone, he said, was so contrived that if they knocked away the foundation of a column the cone would support the column in its place, and the column would support the arches that sprung from it, and the outer roof that hung from it, even when the foot of the column hung in air. The cone was sufficiently strong to carry even two or three adjacent columns with their foundations fallen away. It was so contrived that

if by an earthquake the foundations were moved horizontally, the columns would not follow them, but would maintain their upright positions in their correct places under the dome. If a hurricane could be conceived strong enough to shift bodily along out of place the whole 4,000 tons of dome, the columns would shift place with the dome, and carry it as secure as now in the right place. The secret of this quality, Mr. Russell remarked, consisted in a principle he had not yet adverted to. The characteristic of a homogeneous cone was, that its whole surface consisted in a continuous series of parabolic chains or approximate catenaries in places parallel with the slope of the cone. These parabolic catenaries had the quality that they connected the summit of each and every column with the whole of the opposite, as well as with the adjacent, side of the cone. Each column was, therefore, held in place by the equivalent of a countless number of chains ending in the summit of the column, and pressing with a uniform, even-spread, gentle pressure on the skin of the cone on one side, and also on the opposite place. Further, each vertical section of the whole conic surface was a hyperbola, approximating closely to the inverted catenary, or catenarian arch. If, therefore, they knocked away one, two, or three columns, or their foundations, the mutilated cone still stood upright on all the other columns, standing on a series of catenary arches extending across the whole skin of the dome to the surviving columns, and supporting the roof by catenary equilibrated pressure. The Vienna conical roof, therefore, contained within it strength enough to resist all the strains which could fall upon its supports and connections, and that strength communicated to them through the best possible ways. To utilize this strength one more condition was necessary, that was the perfect unity of the superior structure or roof with the inferior structure or supports. In common buildings the supports, columns, arches, and walls found their strength in broad and deep foundations, whence they carried stability up to the roof. In his building, Mr. Russell remarked, all the stability was derived from the roof, and was given off into the supports by a connection to which he would direct the attention of the audience. The roof rested on thirty, or say thirty-two columns, for there were two small arches at the main entrance. These thirty main columns were neither square nor round. They were 10 ft. through one way, 4 ft. through the other way, and 80 ft. high. They were of the same material as the cone itself, combined in the same proportions, and united in the same way. They were in structure, though not in shape, part of the cone. Mr. Russell then proceeded to explain the reasons for the position and proportions of the columns, and passed on to notice the construction of the foundations, which, he stated, were mere slabs of concrete, which rested on the alluvium of the Danube, and prevented the weight of the dome from sinking down into it. The columns spreading out above, by ribs and rings, over the surface of the cone, might be said to grow downwards from spreading roots above, and merely rested on the ground, as a lame man's crutches, or as the legs of a table on a smooth floor. Their strength came from above, not from below. They lent their strength to serve the strain of all above them, and they got in return the strength and strain of all above them to maintain their position below. No parts could fall unless all else fell along with it. In conclusion, on this head of the subject, Mr. Russell remarked that the cone would stand after it was pierced all over, after its outer and inner rings were cut through, after the outer chain of the cone itself was severed. Indeed, he said, after it was severed into thirty detached fragments, it would stand. Only complete disintegration could bring it down. Indeed, it would cost more time and labor to cut it to pieces than to build it in place.

The remainder of the paper, which was of great length, was devoted to highly interesting remarks upon the history and practical execution of the Vienna building, from which we gather that the general plan, aim, and design of the Great Exhibition in Vienna having been determined in the highest quarters, his Excellency Baron Schwartz Von Senborn, who was appointed sole Imperial Commissioner, was generally regarded as the one man in all Austria best fitted for the task. The general design and aim of the building as a whole was the idea of Baron Schwartz, or those above him. From a variety of considerations, the building required to be of a different character to that of any previous Exhibition in England, or other parts of Europe. The large entrance of the Oriental element amongst the exhibiting nations rendered European plans of classification impra-

ticable, and decided the adoption of the classification of the Exhibition on a principle purely geographical. Mr. Russell then entered into the history of the origin of his large iron dome, and stated that he designed it with a view to the Exhibition of 1851, having previous to that year discovered the peculiar qualities of the conic form with relation to large buildings of modern iron. Circumstances, however, prevented his plan from being carried out; but when in the summer of 1871, Baron Schwartz visited him in England and explained to him his views of his general plan of the group of separate buildings, he (Mr. Russell) was quite prepared with data for him as to the size, character, and cost of a great central cone.

The considerations which settled the size of the Vienna dome were mainly those of cost. It was decided that the central structure, and as much of the surrounding buildings as should be capable of permanent utilization, should be permanent. Mr. Russell then proceeded to describe the manner in which he arrived at the best mode of adapting this large cone to the central position it was to occupy in the surrounding groups of parallelogramic buildings, after which he called attention to some of the points in the conic construction which were of an architectural nature, which he said gave him and those associated with him considerable thought.

The paper was illustrated by copious drawings by M. Hasenauer, from which, Mr. Russell remarked in conclusion, it would be seen that the great dome was not, as many supposed, a mere separate isolated structure, but that it was incorporated with the vast area of smaller buildings all round it, so as to be an integral portion of a whole group.

THE VIENNA DOME.*

We would not anticipate the discussion which is proposed to be held at the Institute of Architects upon the scientific questions raised by Mr. Scott Russell, in his lecture upon the Vienna Dome; but we cannot allow the immediate opportunity to go by for examining, in a spirit of inquiry rather than criticism, certain of the most prominent points in the lecturer's theories.

The case, as it was put by Mr. Scott Russell, may be said to stand thus:—Taking the usual hemispherical dome as representing an accepted principle of construction, irrespective of differences of material; and looking at the malleable iron of the present day as a material of peculiar characteristics,—then the conical principle is seen to be preferable to the hemispherical for the use of iron; and not only so, but the construction of a conical iron dome is found to be the scientific perfection of building contrivance.

In the case before us the diameter is shown to be 360 ft.,† which is certainly what our Transatlantic cousins would call "a big thing." But the enthusiastic "worker in iron" went on to say that he had at first proposed it to be as much as 800 ft. in diameter; and he seemed indeed to have a hidden feeling in his own mind, which modesty alone prevented him from expressing, that if the Austrian Government had been sufficiently adventurous, it might have been 8,000 ft., and he at any rate would have never demurred. And, to tell the truth, we do not at first sight perceive any reason why he should object to even still more magnanimous dimensions, except the totally unscientific consideration that, although in one sense it is the mind that is the stature of the man, yet in another it is on an average about five feet six.

The mode of construction, if we rightly understand it, is as strikingly simple as it is ingenious. The circumference is divided into segments of nearly 3½ ft. in length, making 360 of them. The cone is pitched at an angle of 30 deg., which seems to be a very fair condition for the experiment. The 360 divisions of the circumference are then made the bases of as many triangles of extremely elongated form, occupying the surface of the cone, and terminating together in a point at the apex. It only remains further to make these 360 triangles 360 sheets of iron, riveted edge to edge, and presto! the dome is done. If you desire to leave an eye in the crown, so be it; the dome is still complete. If you desire to give to the structure the character of a skeleton frame of open work rather than that of an imperforate vault, so be it again.

* Review of the foregoing lecture by "The Architect."

† By the way the lecturer began his scientific exposition by the remark that his dome was 360 ft. in diameter, and 1,080 ft. round. Such a slip as this was at least discouraging to his audience. We cannot suppose that anybody really puts the circumference of a circle at three times its diameter; but to state the case in this way is popularizing science a little too much.

You may even put a lantern on the summit, and there is no cause for anxiety. Beyond a doubt, all this is refreshing to a degree which, even in these days of brilliant engineering achievements, is most unusual; it gives one's ideas of science a thorough shake-up.

So much for the cone. The lecturer then described the enclosure to which it had to be applied as a roof. This may be called a skeleton "drum" of iron columns, 36 in number, with iron sill and head of circular plan. The sill rests on the ground foundation; and the head constitutes of course the base of the conical roof. The height of this drum is 80 ft. We may suppose that if it had been formed, like the cone itself, as a simple cylinder of boiler plate, the theoretical principle would have been even better preserved; but a peristyle such as has been described was of course preferable for the occasion; and here let us remark in passing that the introduction of this essentially different idea of structure for the enclosure, already suggests the possibility that the cone itself may after all turn out to be, if a structural novelty, certainly not the mathematical mystery which Mr. Scott Russell appears to think it is.

We will now imagine some bold and economical builder to resolve upon constructing a shed upon the conical roof principle. He sets out, we shall say, a circle of moderate diameter, lays in a little concrete foundation, rears thereon a cylinder of common sheet iron with riveted laps, and covers in with a cone of the same material. He cuts a door or two in the cylinder, and leaves an eye at the apex of the cone for a lantern light. He has put strengthening frames round the doors, and the like round the eye; but all else is sheet-iron with perhaps a flange at the sill and head of the cylinder. One can scarcely doubt that this edifice, barring violence, is simply the slightest and the cheapest that can be conceived. The designer has but to select the proper gauges of iron to suit the scale of the structure, and he has attained the supreme satisfaction of having economized his material to the very utmost, and disposed it to the very best advantage as regards both strength and enclosed area. Our old-fashioned idea of securing such perfect economy has been to set out an oblong enclosure and cover it with a simple span roof. But this notion is obviously based upon the use of wood framing, covered perhaps with boarding; whereas the new idea is identified with the application of sheet iron without framing —a material entirely different in every respect. For an example on a sufficiently small scale, and reserving the question of weather, wood boarding would do as well as the sheet iron, with the joints tongued in some way and a solid curb added for the sill and base of the cylinder; and for a model, cardboard would answer admirably; but, if skeleton framing of any kind whatever is introduced, let it be distinctly observed that the principle is changed; and the practical difference between wood boarding and sheet iron is that the one must be put together in widths of a few inches, while the other is supplied in widths of 2 or 3 ft. The question of wear we are excluding from our view, as well as that of resistance to violence; and structurally, therefore, we may acknowledge that Mr. Scott Russell, in affirming that the cone and drum are theoretically a novel idea of construction specially identified with the use of iron, is quite right.

But there are two or three statical arguments advanced by Mr. Scott Russell, which he must not, without at least farther explanation, ask everybody to accept as genuine. First, there is his doctrine of the antagonism of parts. Referring to girder construction, as also to trussing—let us say in the case of a timber girder, a box beam, a latticed bearer, a king post roof truss, a bow and string bridge, and an iron arch rib respectively—when we perceive, as we must admit we do, that there is everywhere an upper flange or its equivalent in compression, a lower one in tension, and an interposed web or its equivalent to preserve the element of depth (the strength being always as the square of the depth or its equivalent), he seems to tell us this:—There are here three separate forces, each of which has for its sole function the antagonistic resistance of the other two; the whole three are therefore adjusted to a perfect balance, and the failure of one of them produces the immediate destruction of all; wherefore we simply have three equal agents at work in counteraction to each other, so that two of them are manifestly waste. Surely this, if we take it aright, must be a mistake. We may grant him for the sake of argument that the web of a plate iron girder carries none of the load; but it keeps the two flanges at the required distance; and when these, so kept

at that distance, act one against compression and the other against tension, the conclusion must be that both support the load, and not either; that the strength is one of addition and not of subtraction; and indeed it must be plain upon a moment's reflection that even our imaginary cone of thin sheet iron must have its compressive and tensile strains distinctly marked within its thickness. We are ashamed to introduce such an illustration here, but suppose an army to consist of three arms of perfectly equal force, infantry, cavalry, and artillery; it is obvious that this arrangement would be utterly destructive of the entire army if the three arms were set to fight amongst themselves; but if they co-operate against the enemy, that is quite another case. The two flanges and the web co-operate apainst the load, and it is vanquished; if they were no more than "antagonistic parts," the girder, to quote another idea of our lecturer's, would forthwith upon the first twist "go into gas."

Another doctrine advanced by Mr. Scott Russell is that of the co-operation of parts. In the iron cone, he says, the material is not only relieved from the condition called antagonism of parts, but it is endowed throughout with a positive quality of the opposite effect. He even went so far as to suggest, as it seemed, that every particle of the metal is placed in a state of both compression and tension, as opposed forces, a proposition which is as essentially mistaken as that of the perpetual motion. At any rate, he further affirmed, the cone and the drum, taken together, albeit the latter is a peristyle, are in such a state of perfect equilibrium, that if part of the cone were to be cut out, nothing would happen; if some of the columns were to be removed, nothing would happen; if a hurricane blew, nothing would happen, except it were the propulsion of the entire edifice along the ground; if the building were blown up with gunpowder, this would merely make a hole in it; if an earthquake occurred, no harm could be done further than some tilting of the whole structure out of level; and if the foundation gave way—well, it did not require any foundation at all, except as a kind of concession, we presume, to popular prejudice. Nay, such are the harmonious and homogeneous relations of all the parts to each other, that, if anything such as a rivet could by any impossible stretch of fancy be supposed to give way, the only result that could be conceived, said Mr. Scott Russell, would be that the entire building should "go into gas!"—a sufficiently impressive conclusion, and most forcibly asserted, but one which at least is not quite so serenely scientific as could be desired.

One other point which requires elucidation is the argument that the cone keeps the peristyle guaranteed against such an accident, for example, as the knocking down of half-a-dozen of its columns, by the existence within the substance of the iron cone of an infinite number of "parabolic and hyperbolic catenaries" which tie the head of every column to that of every other, and so render them not only immovable if untouched, but in no respect indispensable if they should be capriciously taken away. Upon this remarkable proposition we really cannot venture to make a single remark, except it be by way of inquiring whether we can possibly have heard aright. The catenary curve, argued the lecturer, is of course the curve of equable strains. But the parabola is not far off the catenary curve; the hyberbola also is a sufficiently close approximation to it. Suppose, therefore, that we accept these two conic sections to stand for the catenary, which is not a conic section. Suppose next that we draw upon the surface of the cone an infinite number of these two curves, the one corresponding with planes that are perpendicular, and the other with planes that are in every variety inclined. Then it follows, if we be right, that any threatened disturbance of any point in the circular head of the peristyle immediately sets up within the substance of the cone, the action of an infinity of parabolic chain-ties, equivalent to catenary arches, communicating with every other point in the circumference, and an infinity also of hyperbolic chain-ties, equivalent to catenary arches, similarly operating; whereby every point in the circle comes to be supported from every other point in the circle, and that in such a way as to correspond fully with the idea of infinity which is involved in this description. Can this really be the meaning of our learned doctor in iron?

Let us now turn for a moment to the common theory of the strength of domes in stone, and apply it to the case at Vienna. There are of course two modes of construction to be considered. In the one case there is a skeleton of vertical ribs carrying the

covering between them; in which case the ribs must be equilibrated or otherwise secured against the cross strain of the load.

In the other case there is a series of rings; and in this instance each ring must be preserved against tension by chain bond. The latter of these two systems is identical in principle with the iron cone; the entire dome is placed in tension by its own weight; and the pressure of wind or snow increases the tension. But the equilibrium depends, if upon nothing else, upon the perfect equableness of this strain over the whole structure; and likewise upon the perfect balance of local strength in every part. To say that the whole edifice must either remain intact or bodily disappear is idle. How then is it to fail, when it does fail, as all things must? By nothing at all miraculous or even mysterious. In course of time, even with the most complete equilibration of design and the most liberal margin of stability, some part of the dome will buckle by the accident of weak workmanship; or some joint will open by the shearing strain of which the lecturer spoke so disrespectfully; or some column will settle in spite of his defiance of the foundation; or the mere irregularity of the wind or snow and the expansive and contractive influences of the temperature will bring about creaking and crankiness, which, once begun, must go on increasing in a geometrical ratio until the whole of the gigantic shell is crippled. It is not a theoretically regular pressure resting upon a theoretically immovable vault that is in question; but it is a variety of palpably irregular strains coming at will upon a mere fallible roof, exquisitely light and economical in itself, no doubt, but all the more on that very account susceptible to all such misadventures. We have only to revert, in short, to our primitive sheet iron shed, and to ask ourselves the question how this frail edifice is to break up when it does so. Let the sun's rays beat upon it for a year or two; let the winter frosts freeze it; let the north wind blow against it; let the foundation settle a little here or there. Very well, says Mr. Scott Russell, let them do their worst; there is a virtue in the circular principle of the roof-cone which nothing of that kind can conquer. Nay, we may fancy him saying, my cone is like the chain of perfect equilibrium itself; hang it up as you please, level or out of level, it is always the same; cut off a part of it, great or little, and it still retains its form; leave but a shred of it and it is a shred of the catenary; cut it in a hundred places and there are but a hundred bits of the same catenary; such a thing is perfect equilibrium! All which is in theory most admirable, at least so far as it goes. But nevertheless, our shed would go the way of all sheds, and heat and cold, wind and decrepitude, would scarcely care to snap their fingers at our theories, so sure are they of their prey. Our sheet iron bee-hive would simply "give way somewhere," and there is in this vernacular mode of expression something quite as much of the infinite as in all the fine-spun fancies of the "parabolic and hyperbolic catenaries." The thing would most indubitably give way somewhere; and the meaning of this is that so soon as the margin of stability happened to be reached in some unexpected spot, then inevitably must that spot become the "weak point" upon which all the natural agencies of wreck shall concentrate their forces until a breach be made.

A last question shall be this:—Why prefer the form of the cone to that of the curved dome? Although there is no special virtue in the mere circularity of an arch, except as the representative form of a corresponding equilibration; and although indeed the earliest of all arches is the simplest, namely, that of the narrow passage in the Egyptian pyramid where two stones lean together in the form of the inverted V (Λ), yet an arch is an arch in whatever material, whether as a stone bridge or a cambered beam, and then why should the Vienna cone be pitched in a straight line and not in a curve? Is there, as matter of fact, any camber in the 360 triangular sheets that radiate round the lofty eye of the structure? If not, why not? If so, then where is the cone as distinguished from the dome?

It is not perhaps perfectly easy to say what are the æsthetics of the question, but certainly we may venture to imagine that most architectural critics, if not all, would pronounce the straight slope of the Vienna roof to be clearly inferior in graceful form, and still more so in the particular effect of impressive grandeur, to a curved slope of whatever pitch, that is to say, a common dome of whatever elevation from the most oblate to the most pointed. If so, we can see no reason why Mr. Scott Russell's mode

of construction should not be applied to the curve as easily as to the straight. It is but to set out his elongated triangles as spherical instead of plane; this is easy enough, and the riveting of the flanges is the same; and if one had any momentary misgiving about the manipulation of bent iron, they instantly disappear in view of the magnitude of the dimensions, by which the necessity for bending, even vertically, becomes virtually nil.

One thing which we must remark is that Mr. Scott Russell's description does not appear to include anything like vertical ribs in the construction of the cone, although the photographs indicate something very like them. If there are ribs of any kind at all, the question is whether this does not overthrow the entire argument about the peculiar virtues of the conical form.

On the whole we take leave to submit that the case for the peristylar enclosure or wall work is not made out at all; and that the theory of the cone, although its practical excellence and intrinsic novelty are unquestionable, requires further elucidation or none at all. But we congratulate Mr. Scott Russell very heartily upon the enterprise of thought which characterizes the whole of his discourse upon the subject.

COMPASS ADJUSTMENT IN IRON SHIPS.*

From "Nautical Magazine."

There is no instrument in an iron ship on which life and property so much depend as the compass. There is no instrument that equals it in being answerable for so much loss; and there is no instrument, I fear, that gets less practical consideration. To a certain extent, the laws which govern other instruments come within easy range of our comprehension, and we can compensate for changes, or ascertain errors and rates, and the mischievous influences they are subject to; but the magnetic disturbance of an iron ship is so subtle in its action, and assumes such various phases, and is so continually changing with change of locality and other causes, that it becomes exceedingly difficult to govern by any permanent method. Indeed, so far, it cannot be done.

It is not necessary that the navigator should be able to make a chronometer, or that he should understand all its complex mechanism. All this, and its rating, he may safely leave to its maker, and every additional chronometer he carries answers the purpose of being a check, and making his position more certain. But it is otherwise with the compass. If he leaves this exclusively to its maker, without testing either its action or adjustment, he imperils life and property by his short-sighted trust; and, so far as a change of magnetic disturbance is concerned, any number of compasses he may carry are no more use to him than one, as every change affects the whole.

The navigator will, therefore, do well not to place any dependence on his compass, until he has himself tested its quality, its suitableness to his ship, and the value of the adjustment. To do this as early as opportunity offers, on a voyage, ought to be regarded as an imperative duty. On his own knowledge only of the compass should he risk life and property in shaping a course, and not on an irresponsible adjuster, whose adjustment after all, even if properly made, is of limited value, except for the locality of the adjustment.

Although life and property are so dependent on a compass adjuster, any one that chooses can set up as one. Without he is a well-known man, there is no guarantee that he knows anything about the duty he undertakes to perform. He is not called upon to pass any examination, or hold any certificate, and as he may be dependent on patronage in his business, he can consequently give no guarantee to life and property, that he can take an independent stand, and stave off the pressure that may be brought to bear upon him to do his work in one-twentieth of the time necessary. In shaping a course, therefore, on a thick night, in a narrow channel, with much life at stake, what confidence is he calculated to inspire, or is he worthy of? The over-confiding navigator, unfortunately, gives him too much, and, consequently, too often comes to grief.

But, supposing the compass adjuster not only to be thoroughly acquainted with his duty, but getting his own time to do justice

* A paper read by Captain John Miller, at the Liverpool Mercantile Marine Service Association.

to his adjustment. When shaping a course down-channel on a thick night, to what extent can his adjustments be relied on? His method of adjusting and obtaining his tables is very fallacious and very incomplete. In a still-water dock, with an upright ship only, surrounded with a crowd of iron vessels, he places down a number of permanent magnets, swings the ship, and takes a table of deviations. How long do these tables hold true? In some cases just as long only as the ship is in the dock. But, doubtless, after a voyage of constant changing, when under the same condition of things he again swings the ship, he will obtain the same results. This return of the compass to the original deviations, has often led to the erroneous conclusion that there has been no change since the original adjustment, when the truth is, the compass has never been the same from the time the ship left the dock until she again returned to it.

The table of deviations, handed to the navigator, often shows a balance of the ship's disturbance, amounting to a whole point or more of the compass, remaining uncompensated. When it is remembered that a disturbance that produces on any one point such a deviation, destroys on another point one quarter of the whole directive force of the needle, it will be seen how unreliable such a compass would be, going at any great speed, on a dark night in channel, when a good lookout would be little or no preventive against loss. In such cases it is highly important to the navigator that the strange vagaries that such a compass, on some points, is liable to should be well understood, for he may be unconsciously steering on the very point on which the directive force of the needle is most destroyed, and then he is very liable to go wide of his intended course: the weather, if rough, and the heeling having a great deal to do in influencing the course the ship will make.

These tables, again, are calculated to mislead those who do not study the compass for themselves; for the tables are not limited in their application to any locality, but handed to the navigator in a form as though they applied to the whole surface of the globe. Doubtless, many have regarded them in this point of view, and some have come to grief in other seas through them. Now this is a very loose state of things. One would think that life and property are of sufficient importance to command something more definite for their interests. Surely, when the consequences may turn out as serious as the loss of the Atlantic, the adjuster ought to be more explicit; and, if it were only to prevent misleading, he ought to make it appear in his tables what, in his judgment, would be the range of their reliability, and for what extent of the earth's surface he intends them to assist the navigator in shaping a course.

But the greatest fallacy connected with these tables consists in its being taken for granted that the amount of deviation given on each point shows the whole influence of the ship's disturbance. This is far from being true. The ship is a huge magnet; or, more correctly speaking, one large magnet, and a number of smaller ones indiscriminately placed, and revolving, as the ship steers on different courses, under the compass. When the influence of the disturbance is acting at right angles with the needle, it then produces on the compass the greatest amount of deviation, and it is only when there that the amount of deviation may be said to show the full value of the force of the disturbance. On many points it shows a reduced value, and on some points it shows none, though the disturbing medium is in no way removed from the compass, but is operating for mischief equally on the point which shows no deviation, as it is on the one showing the greatest.

To make this plain, let us suppose our performing the following experiment:—Having a single needle compass, let us obtain another needle or magnet of the same magnetic force. Let us place this magnet on the card of the compass. It will be evident what will be the effect, if we place the North Pole of the disturbing magnet on the north of the compass, with the South Pole on the south. The needle and the disturbing magnet will, of course, in this case be acting together, and there will be no other effect than that of increasing the directive force of the compass. But let us next place the disturbing magnet on the N. E. and S. W. points. The result will be to produce a deviation of two points. The N. N. E. point will then take the place of the north and point to the magnetic pole. Next let us place the magnet on the east and west points, at right angles with the compass needle. In this position, the disturbing magnet produces the greatest deviation, which in this case will be four

points, the N. E. point now taking the place of north.

Now, it must be evident that while the North Pole of the disturbing magnet is on any of the north points, the directive force of the compass must be more or less increased. These points, therefore, become steady ones; and, after applying accurately to them the deviation, they will make satisfactory courses.

But when we place the North Pole of the disturbing magnet on the south points, the action of the compass is very different. It loses its steady nature, becomes fickle and oscillating, and unreliable for making a course; because, in this case, the directive force of the needle is more or less destroyed, according to the position of the pole of the disturbance. Let us place the North Pole of the magnet on the S. E. If the result be of the same uniform character as with the experiments on the north points, the deviation ought to be again reduced to two points. But there is nothing uniform in the action of the compass, when the disturbance is thus neutralizing the directive force of the needle. It will make a course according as it is influenced by the ship's heeling, or rough weather. At one time it will show one deviation, and at another time another; and it has, consequently, often led to the conclusion that the ship's disturbance was subject to sudden and great magnetic changes. In 1854, the late Dr. Scoresby contended with the Astronomer-Royal that it was so subject; and, in the loss of the Tayleur, he tried to prove that it had taken place, and was caused by the heavy blows of the sea. But time has shown that this was not the case. There was no change of magnetic disturbance. The directive force of the disturbance was simply acting against the directive force of the compass, consequently neutralizing it; and the ship and nearly 300 lives were lost.

With the disturbing magnet on the S. E. point, the deviation is but little less, and the compass has but one-half of its directive power neutralized. Let us next place the North Pole of the disturbance on the S. S. E. Here the deviation shown will be considerably reduced, but the compass has three-fourths of its directive force destroyed, and is almost useless, though the deviation given is but small.

This shows how important it is to the navigator to know how the disturbing force is operating on the course, whether it is increasing or decreasing the directive force of his compass, and this he must work out for himself, for from an adjuster's tables he can learn nothing about it. This shows also how these tables may mislead the navigator, by ministering to a false security, for as they do not show anything of the increased or decreased magnetic force of the compass, the small deviation given on some points conveys the erroneous idea of a small disturbing influence acting on the course, while every compass has, acting on each one of its points alike, a disturbing influence equal to its maximum deviation, the whole, in one case, going to increase the directive force of the needle, and in another to neutralize it; and in two others, when operating at right angles with the needle, to produce circular deviation exclusively.

If we now place the North Pole of the magnet on the south of the compass, with the magnet we have supposed, the whole directive force of the compass will be destroyed. But let us suppose, for this point, the power of our distributing magnet reduced to two-thirds the directive force of the needle. The compass will then act, but there will be no deviation produced. The needle will point to the magnetic pole as though no disturbing magnet were there; there is no effect to produce deviation, the whole force of the disturbance having gone to neutralize two-thirds the directive force of the needle.

In these experiments, I have supposed our using a disturbing power equal to the directive force of the needle, which will always produce four points deviation. But it is not to be supposed that, in these days, any ship goes to sea without having such a disturbance reduced by compensation. My object in using a magnet of equal force, is to show a rule of measurement of the disturbance, which will always be more or less useful. Thus we know, for example, when the maximum deviation amounts to four points, the disturbing force is just equal to the directive force of the compass; and, consequently, when the forces are acting reversely, the compass is dumb on one point, and nearly so on others. When, again, the maximum deviation is two points, the disturbing force is just one half; and when there is but one point, the disturbing force is one quarter, and there will, of course, be half and quarter results.

It will, I think, now be seen that every iron ship's compass, having an amount of

uncompensated disturbance remaining, must have all its points affected for steadiness or fickleness. Steadiness, when the proper pole of the disturbance (which will be the south when it is free from the compass) is acting on the north, and fickleness when the reverse. I use this latter term to distinguish it from sluggishness. A compass becomes sluggish only from its own defects, such as defective pivots and agates. These, when defective, give rise to an action —or, rather, want of action—which is very appropriately called lazy, or sluggish. But fickleness, arising as it does from other causes, and which affect alike with the sluggish the most perfect compass, shows itself, not in a want of action, but in an action peculiar to itself, and which heavy-weather motion will develop into oscillation.

These fickle points sometimes show themselves as soon as a ship is at sea, if the ship's course happens to be on one of them, and there is sufficient lift of a sea to make them active. They become apparent when the helmsman, without noticing the ship's head, attempts to steer by the compass exclusively. In this case he labors hard to steer. The wheel is not one moment at rest in his hands, and it is one constant grind with him, in his abortive attempts to keep the course and lubber point in one.

Heavy weather develops these fickle points into points of oscillation in high latitudes, and the compass, while the ship's head is on one of them, becomes of no use for steering purposes; and while swinging a ship at sea, by a process which I shall now explain, they often give different results.

By this process of swinging, the navigator can test for himself the quality or action of his compass, the value of the adjustment, and the deviation table taken in the still water of a dock. He can also ascertain the steady and the fickle points, and measure the amount of fickleness left by imperfect compensation, or produced by permanent compensating magnets, after sailing into localities for which the adjustment does not answer.

With the aid of the stile on the compass, which I invented many years ago, and published in 1854 in the July number of the "Nautical," and which is now very generally attached to a steamer's compass, it is a simple and speedy process to swing the ship at sea, and obtain, by the shadow of the stile on the card, the bearing of the sun, or magnetic azimuth on every point of the compass, as the ship goes round. As many compasses can be taken at one time, as there are reliable observers to read the position of the shadow as the ship revolves. Suppose there are four good observers and four compasses, four ordinary men will do to assist them, by intimating the moment the ship's head is on each point, so that the observer's attention is not taken from the shadow, except to mark down its bearings in prepared tables. One compass, the standard, can be taken for navigating purposes exclusively. Three compasses will then be left to perform any experiment that suggests itself to the navigator. He can leave the second one with the adjuster's magnets surrounding it, if he wishes to test the value of dock adjustments. From the third, he can take away all the magnets, to obtain what I call the natural deviation—that is, without magnets; and, if he already knows the natural deviation of the fourth, he can apply one compensating magnet to learn the value of its effects; and, in after swingings, this magnet can be tested for every variety of position and place. With all the results noted, the whole can be repeated with two magnets, and afterwards with three, and so on to any number, until he understands the value of every variety of compass adjustment, or until he has discovered perfect compensation, or is satisfied it cannot be obtained.

The first thing to be considered before swinging is, whether the sun will remain unclouded for half an hour. If satisfied that he will be able to cast a continuous shadow for that time, the observers may take their stations, each one being supplied with a blank table, having in its first column the points of the compass. Any point will do to commence on; but let us suppose we are steering S. W. by W. We then give the order to the observers to commence their notings on west. The speed of the ship is then slackened to nine knots, the altitude of the sun is taken, and the helm is hove over to hard-a-port. The ship gets up her full revolving speed by the time she reaches west, and the notings of the shadow on each point of the ship's head then takes place as the ship flies round, which she is allowed to do, until she reaches W. N. W., when the helm is immediately hove over, hard to starboard, and the readings again commence when the

ship reaches west. The ship flies once more round, until the last point to be noted is reached, when the sun's altitude is again taken, the ship set on full speed, and put on to her course.

The time taken with the two revolutions is about 25 min.—an insignificant loss in a ship's passage, compared with the value of the results to life and property. By this simple process we obtain the means of knowing whether there is any defect in the compass itself; whether the adjustment is of a respectable character, and how far for making a course the compass may be relied on. It will, of course, take some time to work four compasses, and all the problems necessary to complete the tables; but the navigator can work them as he obtains leisure, and they are not, in spite of their numbers, half as difficult as they may appear. By applying a little method, and with a little practice, the difficulties presented by the imagination soon vanish.

Before working them, however, a mere glance down the columns of bearings will reveal much of the state of the compass; for, if it was without disturbance, there would be no variation in the whole revolution of the position of the shadow on the card, except the little due for change of sun's position. Revolving the ship different ways will, of course, give different results, owing to the ship, while going round, dragging the card after her. This dragging, however, can be turned to account. We can make it reveal to us the state of the pivot and agate.

Looking down these columns of bearings, you can see whether it is worth the trouble of working them, or whether it will be necessary to have the compass re-adjusted. If the changes in the readings are not uniform, but very irregular, and the shadow has taken one or two great jumps, while the ship's head has passed from some one point to the next, you at once see whether they are worth the trouble of working.

If deciding in favor of working them, the next thing to do is to obtain the sun's true azimuth by the two altitudes taken. The difference between these, divided by 64, for the number of points, will give the amount of change of the sun's true azimuth for each, amounting somewhere to about five seconds. It is easy to write down continuously for the heads of problems the whole 64 points of the sun's true azimuth from mental calculation. Next place underneath each the magnetic azimuth for every point. Next take the difference for the whole 64; next write down the variation under the whole of the problems, which must be accurately obtained for the ship's position from a chart of magnetic curves, and next apply it by adding or deducting from the whole error, according as they turn out of the same or contrary names. With this method and a little practice, the working out of the whole 64 problems for each compass will soon become a mere mechanical performance, worked out as fast as black lead can be made to travel.

With, then, the port and starboard helm deviations worked out, enter them in the fourth and fifth columns. Next work out the mean deviations, and place in the sixth column. Next take the difference between the two deviations, and place in the seventh. Add up this column and divide the sum by 32, the number of points. The remainder will be the mean drag of the card, and the amount that would be shown on every point, if the compass was free from magnetic disturbance. The eighth column-head as, Steady Points and Value, and the ninth column-head as, Fickle Points and Value, and proceed to work out and fill up each column, thus:—Take the difference between the mean drag of the card and the difference between the port and starboard deviations. When the latter is less than the drag of the card, the difference is the value of the increased directive force, which enter into the column of Steady Points; but when the difference between the two deviations is greater than the drag of the card, the difference between the two is the value of the decreased directive force, which place in the column of Fickle Points, and the table is then complete.

I have before me now such a table for a steamer's standard compass, elevated 18 ft. above the deck. This table has been selected out of many; because, the compass being defective, and a standard compass of such elevation, any defects in its action will better illustrate this paper, for from such a compass we naturally expect the best performance. I have chosen it, also, because it shows as great a deviation as is safe to leave uncompensated on any compass on which we have to depend for making a course in such a high magnetic latitude as the Channel.

CALIFORNIAN, *s.s., Standard Compass Deviations, Revolved April 22d, 1873, Lat. 50 deg. N., Long. 13 deg. W.*

1. Compass Points.	2. Port Magnetic Azimuth.	3. Starboard Magnetic Azimuth.	4. Port Helm Deviation.	5. Starboard Helm Deviation.	6. Mean Deviation.	7. Diff. of Port and Starboard Deviations.	8. Steady Points and Value.	9. Fickle Points and Value.
North	S. 45° E.	S. 28° E.	16° 57″ E.	8° 1″ E.	9° 59″ E.	13° 56″	.....	0° 16″
N. by E.....	45	27	17 5	1 53	9 29	15 12	....	1 31
N.N.E.....	42	25	14 13	0 15 W.	6 59	14 28	.....	0 47
N.E. by N..	41	20	13 21	5 23	3 59	18 44	....	5 3
N.E.....	38	17	10 29	8 31	0 59	18 59	.....	5 19
N.E. by E..	31	15	3 37	10 39	3 30 W.	14 16	.....	0 35
E.N.E.....	28	15	0 45	10 47	5 1	11 32	2° 9″	
E. by N.....	25	15	2 7 W.	10 53	6 31	8 48	4 53	
East.....	22	10	4 59	16 3	10 31	11 4	2 37	
E by S.....	18	10	8 51	16 11	12 31	7 20	6 21	
E.S.E.....	15	8	11 43	18 19	15 1	6 36	7 5	
S.E. by E...	13	6	13 35	16 27	15 1	2 52	10 49	
S.E.....	17	0	13 48	22 19	18 1	8 36	5 5	
S.E. by S...	18	0	12 35	22 27	17 31	9 52	3 49	
S.S.E.....	20	3	10 27	19 35	15 1	9 15	4 26	
S. by E.....	22	10	8 19	12 43	10 31	4 24	9 17	
South.....	24	13	6 11	9 52	8 1	3 41	10 0	
S. by W....	30	14	0 13	8 59	4 36	8 46	4 55	
S.S.W	35	17	5 5 E.	6 7	0 31	11 12	2 29	
S.W. by S..	38	20	8 13	3 15	2 29 E.	11 28	2 13	
S.W.....	42	20	12 21	3 23	4 29	15 44	.....	2 3
S.W. by W.	45	24	15 29	0 29 E.	7 59	15 0	. .. .	1 19
W.S.W . ..	45	24	15 37	0 21	7 59	15 16	.....	1 35
W. by S....	53	24	17 45	0 13	11 59	17 32	.....	3 51
West.....	50	27	20 55	3 5	11 59	17 48	.....	4 7
W. by N....	50	27	21 1	2 57	11 59	19 4	.....	5 23
W.N.W.....	55	25	26 9	0 11 W.	12 59	26 20	.....	12 39
N.W. by W	55	25	26 17	0 41 E.	13 19	25 36	.....	11 55
N.W.....	53	27	24 25	2 33	13 29	21 52	.....	8 11
N.W. by N..	49	30	20 33	5 25	12 59	15 8	.....	1 27
N.N.W.....	49	28	20 41	3 17	10 20	17 24	.....	3 43
N. by W....	47	28	18 49	3 9	10 59	15 40	.....	1 59
	42	30			32)	438 36		
	30							
					Drag of Card	13 41		
2)	72							
2)	36							
Inner Deviation	18							

I have before intimated that when revolving the ship, if there were no magnetic disturbance, the shadow of the stile would be stationary on the card, excepting the little alteration due for change of sun's position. In the second column of this table, the difference between the highest magnetic and the lowest is 42 deg., so that while the ship was revolving with her port helm, the north point of the compass was moving forward and backward through an arc of 42 deg., although elevated 18 ft. above the deck. This column shows also a jump of the shadow as the ship revolved from N. E. to N. E. by E., amounting to 7 deg., and another jump as she passed from W. S. W. to W. by S., of 8 deg. The sixth column, giving the mean deviation, shows the maximum to be 18 deg. 1 min., and occurs on the S. E. point. The drag of the card, deducted from the 8th column, is 13 deg. 41 min., which is a very high drag, and proving the compass to be very sluggish and defective, though it had answered very well on the voyage while crossing the rough Atlantic homewards. It was, however, unfit for a smooth-water channel. The card which had only a single needle, was therefore condemned, and with a new double-needle card and pivot, after revolv-

ing the ship again on the following voyage, in about the same locality, viz., in the Channel, the drag was 4 deg. 20 min. The drag of the card increases with the increase of latitude, consequent on the increased dip of the needle, and is very small in low latitudes. In columns eight and nine the highest value of the increased directive force shown on the S. E. by E. point is 10 deg. 49 min., and the highest for the decreased directive force is 12 deg. 39 min., and on the W. N. W. point.

It would extend this paper to too great a length to go any further into the subject. The amount of change of the compass between this and the magnetic equator, and the effects of applying one or many permanent or movable magnets, could only be illustrated by numerous tables; and I think this paper has already gone the usual length of such productions. I shall therefore leave the further consideration of the subject until some future opportunity, as I wish, before concluding, to apply what has been said to the late appalling disaster, the loss of the Atlantic, and inquire how far the compass had to do with it.

The inquiry held on her loss accounts for it by the absence on the part of the commander of the use of any of the ordinary precautions in approaching land. All this is very well so far as it goes. But for those who have to navigate life and property safely in similar circumstances, something more is wanted; something that is more defined to the perceptions, something that the understanding can erect as a beacon to warn of the precise nature of the danger, and the something that was the cause of this absence of all the ordinary precautions in approaching land.

Like the compass, man also is subject to disturbing influences; and these often produce on him extraordinary deviations from his general course of life, even sometimes to the extent of neutralizing all his directive force for discharging the claims of duty. This is as true in business as it is in anything else. The successful man of one time becomes the unsuccessful man of another, and the man of well-known ability sometimes commits greater mistakes than one with an ordinary amount. No one's life is free from disturbing influences. The navigator is not exempt any more than others from this general failing, and when it occurs with such dreadful consequences, as in the case before us, it is very desirable to know what was the nature of the disturbing influence, and in what form did it operate on the commander's mind to produce, with such a host of life and so much property at stake, such a great effect as the neglect of all the usual precautions in approaching land.

The natural influence operating on every man with so much life and property in charge, and driving a ship on a dark night at such a speed towards land, is to make him feel exceedingly uncomfortable and restless until he has adopted some precaution to satisfy this great call to vigilance and action in his nature. No one is exempt under such circumstances from this call. It is the voice of intelligence stimulating to caution, and will produce it, unless there is some disturbing influence in the way. It will not be silenced, but will banish from the subject all rest and sleep until he meets its promptings and satisfies its claims, either really or supposed.

In the case of the Atlantic, the judgment of the Court intimated that no precaution had been used. The question thefore is,—How were the calls of this voice in her commander silenced? For though he seemed to have responded to it when he kept watch on the bridge from eight to twelve, he nevertheless afterwards lay down and slept, and slept soundly too, a sleep that proved the sleep of death for many hundreds of human beings. This sleeping was an impossibility, without he had previously worked out in his mind something on which he could rely; and as he did not resort to any of the usual precautions, it is evident that, on whatever he was relying, he was doing so with unlimited confidence, and one that with him seems to have precluded the necessity of having to resort to anything beyond.

On what, therefore, could he have been relying? It was not the lead, for he did not use it. It was not his distance run each hour, for he took no steps to obtain accuracy; and it was not any special look-out, for there were no extra orders given. The question is inexplicable, unless we conclude that it was his compass and his course.

It can be easily understood how the usual precautions may be neglected, and the navigator even obtain sleep under such circumstances, when he has fixed in his mind that the course he is steering will

give proper results. No doubt, when shaping his course, he did so with the intention of making Sambro Light, either right a-head or a little on the port bow, and this confidence he seems to have had in so making it, explains why there was the absence of the use of every other precaution. All these extra precautions would appear very superfluous to a mind already satisfied of being certain to make the Light, and he evidently was carried away by the feeling that he would not only make the Light in time to avoid danger, but also in time to make it worth while to slacken speed for daylight.

This confidence in the compass may have been acquired through previous voyages, making lights as expected, when steering on her regular voyage courses; and this was doubtless added to by the one precaution which was certainly made, viz., that of obtaining an azimuth after bearing up for Halifax. But it is a mistake to suppose that because the compass will give good results steering on some points, that it will therefore do so on all, or that one azimuth will show the compass to be reliable. It may do so when steering on any point where the directive force of the needle is increased by the disturbance, but it is otherwise if steering on any of the points where this directive force is more or less neutralized, and any change in the ship's heeling would make its action more uncertain.

If there is any truth in this reasoning, it follows that it was the unlimited confidence exercised in the compass that was the disturbing force which produced the neglect of all the usual precautions in approaching land, and led to this terrible disaster.

In conclusion, I have to say that it was the loss of the Atlantic that suggested this paper, and I therefore feel that it would have been incomplete without some reference to it. Not that I have any wish to cast reflection or sit in judgment on the unfortunate, but because I have a wish to contribute my mite towards the prevention of the recurrence of such dreadful catastrophes.

THE HYDRAULICS OF GREAT RIVERS.

From "The Building News."

The largest rivers on the earth are those of South America, and M. Revy undertook, a few years ago, to survey the Paraná, the Uruguay, and La Plata; the last, however, being an estuary of the South Atlantic. The main purpose of the examination was to settle some difficult and obscure questions of hydraulics, which, in Europe, could not be determined, since neither the Rhine nor the Danube are of sufficient vastness and power to be taken as criteria. And, as it happens, the three mighty watercourses of the world were within the limits of the Argentine Confederation; great in their depth and width, and, even to this day, in their upper channels, unexplored. But, assuming that where their course is known, it is an excessively onerous task to trace their lines of practicable navigation; their banks, currents, tides, and winds; the nature of their beds; the geological formation of the surrounding country—and particularly so when a flood, pouring down, hundreds of miles, from undiscovered sources, is, at its narrowest, equal to the breadth of the British Channel. The engineers engaged, indeed, confessed that all their levellings failed to disclose the actual fall of the Paraná; that numbers of their experiments were of scarcely any practical value; and that, with a river to deal with many times larger than any in Europe, they were continually baffled. Their measuring rods, floats, and plummets were perpetually deceiving them; their planks, poles, and chains often failed at the critical moment; and the work was carried on under every possible circumstance of discouragement. Their first efforts were directed towards the Palmas branch of the Paraná. Up this they sailed a hundred miles without hitting upon a suitable spot for the commencement of their investigations, as if the point where a river pours itself into the sea were not the most important of all. They then made important observations. The water beneath them varied from a depth of 70 ft. to one of 170, a fact of no good omen to the future commerce of those regions. It was found, too, that the Paraná, like the Nile, is subject to periodical rises and falls, far beyond the tidal reach, and due to the variation of the rains—that is, so far as the truth was ascertained by the American expedition. A

ship's log, although a valuable apparatus at sea, was found to be of little use. Current meters exhibited more distinct results; but even these represented the superficial rather than the principal current of water; and even then the drifts of sand and soil were apt to interfere with the action of the machinery. Boats had to be stationed on the watch; remarks had to be recorded every 5 min.; electric wires were touched; bells were sounded; and at intervals temporary observatories established. In the result, the "River Plate," popularly so-called, is discrowned from its position next after the Amazon, as "The Queen of Rivers." It is (so the explorers declare) no river at all; but an immense estuary, in which the sea is being perpetually displaced by the sweet waters of the Paraná and the Uruguay, having no drainage area, and no original flood of its own. According to this authority, therefore, we must so far change the configuration of the South American Map as to promote La Plata from the rank of a river to the dignity of a sea, though it is rapidly becoming a marine ruin, crowded with banks, islands, deeps, shallows, lagoons, and a confusion of waves, due, in great measure, to the influence of the sun. There is nothing more interesting in the American report than the memoir on "the interference of the sun." With the appearance of new moons, moreover, violent tidal disturbances are registered, with midnight and morning gales, travelling at the rate of 500 miles an hour. Indeed, such events have been known in connection with those rivers as tidal waves driving the currents back towards their sources, and heaping above them nearly two yards depth of salt water from the South Atlantic. But these waves are too vast to be visible. Their approach is never announced by any peculiar phenomena. Indeed, no universal law respecting them has hitherto been recognized, their fluctuations being so frequent and uncertain, and differing so greatly between the bottom and the surface. The latter is of interest, but not of any considerable importance; the former, by which it is generally possible to determine the mean current, is of the highest value to the hydraulic engineer, with reference to the clearing of channels, the execution of works, and the maintenance of inland anchorages. Nearly all depends upon the inclination of the bed, with the depth and width of scour. But, as an adjunct of the sea, La Plata ought, properly, to have no fall. In association with it, we have the monotonous Palmas river, running only 2 ft. below the common level, irrigating a wearisome grass-land, moistening the roots of interminable willows and poplars, deep throughout, easy of navigation, and with a rise and fall to be counted by inches. This body of water passes by many of those ruins which attest the existence of an ancient civilization in the land, though they are, as yet, unacknowledged and unfixed upon the maps of archæology. But it is, in its characteristics, entirely different from La Plata, though their currents are so intimately associated; the Palmas, in fact, does that which the late Sir James Graham, in a famous speech, ridiculed as an impossibility — it runs for several miles uphill, thus proving the power of a tidal wave, rushing inwards from the sea. Then, with respect to the Paraná, a stream practically unknown in Europe, and with which engineering has had, as yet, little to do, we have ample information stored up in the Hydrographic Department of the Admiralty, but it is not yet offered in an accessible form. The pilots of the Paraná never look at a chart; they grow up in their special profession; they become familiar in their boyhood with the many-channelled stream; they know its every winding, and every tree or timber clump upon its banks, and they are invaluable as pilots; but, as for the country they inhabit, they know nothing about it whatever, nor, with reference to the river itself, have our geographical analysts been much more successful. They say, confessing the ignorance of what is called science upon this point, "it is important this should be clearly understood; it is rarely that we have an opportunity to fathom the laws of nature; the effective inclination, at any point, along the course of a river is a most troublesome quantity: it entirely escapes observation. It is always changing, and we never know what it really is." And now to apply practically the studies of the American engineers. They say, to commence with, that they "never will improve an observation to make it agree with accepted views and ideas." This, of course, is the only principle upon which such surveys can be scientifically conducted; any other would be no more than the bolstering up of a theory. They, in South America, have

demonstrated two facts:—they place the question beyond doubt, that the principles hitherto accepted when the movements of water in open or confined channels were at variance with those of ordinary nature, and that the river navigation of the world is still a supreme difficulty and mystery. Nevertheless, a close relationship has been established between depths and currents, a fact the value and meaning of which it might be impossible to exaggerate. The greatest current, it has been proved, is at the bottom; the lightest, though apparently the most active, on the surface; but by engineering improvements they could be equalized, to the infinite advantage of passenger traffic, trade, and irrigation. No doubt all these South American streams are apt to flood their banks in the rainy periods of the year, while in others, they shrink in their bottoms, and are hardly available for even timber-rafts; yet there are other circumstances which interfere with the proper importance of great rivers. A section may be made anywhere across; but the selection of a fitting place, and opportunity for it, is often a cause of no inconsiderable embarrassment. Every hydraulic engineer can perceive, too, at a glance, that a sudden bend may seriously interfere with the formation and action of currents. "It may create," says a distinguished German writer, "a kind of revolution against established principles and laws. Order and law appear subverted, and confusion to reign supreme." When we reflect upon the immense importance, to all countries, of their navigable rivers, the value of this observation will be manifest. Railways may be of priceless consequence to the community; still no ironway, however magnificent, could compensate the capital of Great Britain for the loss of the port of London. What would France be without the Rhone, the Saone, the Seine, or the Loire? Or Germany, deprived of her Rhine and, all geographical disputations set aside, her Danube, with the dim and narrow ferry at Donauwerth? The Neva is the European gateway of Russia, as the Volga is to her Eastern territories; and most nations have understood and represented, through conservancy and other administrations, the national validity of these interests. But in the Eastern world we can have no practical idea of the problems which have had to be solved by the South American Commissions.

To comprehend their magnitude is possible only by comparison. The Danube and the Thames are no better than streamlets in contrast with those mighty waters. The Mississipi, boastfully called "the father of rivers," though long, deep, swift of flow, and steep of fall, is a rivulet by the side of the Paraná. Of whatever size, however, these volumes of water, whencesoever coming, may be, their distinct demarcation on the map, and a full knowledge of their applicability to the purposes of civilization and commerce, cannot fail to be useful in a high degree. The proper application of the principles to be derived from the survey of great rivers must be productive of improvements, although circumstances may vary their influence. Within a river, for example, in an estuary, it is practically illimitable; while we have it upon the highest authority, albeit somewhat to our surprise, that "by deepening the channel of a river, various effects may be produced which will be beneficial in some respects, and injurious in others." They are difficult powers to deal with—these contributions from the mountains to the oceans. They inundate the land; they fling dangerous bars across indispensable outlets; they silt up to the spoiling of harbors; and, in the case of estuaries, their caprices have frequently been nothing less than ruinous.

In order to the completion of our defective knowledge on these points, and our scientific preparation for the future, the most elaborate apparatus possible has been contrived, with meters to measure currents, vanes to indicate the direction and force of the winds, wheels to throw up any turbid or gritty water which may interfere with the clear flow of the stream, and other delicate mechanisms tending to the development of a science comparatively new. The attention bestowed by the learned classes in the Old and New World upon these inquiries may be readily accounted for. A very large proportion of the information obtained was novel.

Even now the Parana has not been traced to its original fountains, although boats have pushed up against its stream for a distance of several hundreds of miles; while, for the upper regions irrigated by the Paraguay, we have still to depend upon the old Spanish travellers. The crews of surveying craft have, moreover, to be especially trained to their duties, as are the subordinate explorers of such interiors as

those of Africa and Asia. But although the issue of the great American enterprise has not been commensurate with the hopes or the ambition of its promoters, a great mass of information has been added to the knowledge of the world, and a way laid open for future enterprise upon those paths which, according to Humboldt, would reveal more secrets than the monuments even of Assyria and Egypt.

PEAUCELLIER'S PERFECT PARALLEL MOTION.

From "Iron."

Outside the calm concentred world in which mathematicians live and think, there are few, perhaps, who would attach anything like adequate importance to the lecture recently delivered before the members of the Royal Institution by Professor Sylvester, or dream that within the modest title of "Parallel Motion" is comprehended a problem, the solution of which has occupied the anxious attention of many most eminent geometers in this and other countries for some scores of years. Had the question no other interest than this, we might possibly have shared the too-general apathy, and not have felt ourselves called upon to deal with it in these columns; but there cannot be a doubt that the discovery which Professor Sylvester has been the first to make publicly known in England is one destined to work a great revolution in mechanical science, and therefore one in which the majority of our readers will be deeply concerned. In the opinion of the distinguished mathematician whose name is now inseparably connected with the invention, "it will give to the mechanician unlimited command over the means of transforming motion, and is an instrument that amounts to a new vital element of machinery; perhaps the most important addition to it since Archimedes' invention of the screw, about 250 (236) years B. C.; one that raises the theory of link-work to the dignity of a calculus, that enables the algebraist to fashion and write out in his study, by the rules of his science, a working plan for compelling a system to perform some of the most complicated movements that can be required for the present or any future purposes of the useful arts in their most refined and varied applications."

Mechanicians will hardly need to be told that the contrivances hitherto regarded as practical applications of the theory of Parallel Motion have been simply approximations, more or less imperfect, to the desired end.

Parenthetically, and for the sake of perfect clearness, it may be well to say that what is here alluded to under the title of Parallel Motion is in reality the conversion of circular motion into rectilinear, or the contrary, the best if not the most familiar example of which is to be found in the action of the beam and piston of an ordinary steam engine. Strictly the phrase, as applied to a contrivance for connecting the rotary motion of a beam round its centre, with the vertical or horizontal motion of a single rod is indefinite, and to some extent misleading, but by long association of ideas any combination of jointed rods employed for the purpose of causing a point to move in a straight line, or a rod in the direction of its length, has come to be so called. A well-known combination of this kind is the machine or link-work, commonly styled Watt's Parallel Motion. The essential principle of which, disguised in many modifications of form, is to be recognized in almost every mechanical combination for which the character of Parallel Motion has up to this time been claimed; but the parallelism of this invention is neither more nor less than the reduction of the perceptible circular motion to a minimum by carrying it through many changes of direction. This is accomplished by means of poles travelling in contrary curves; the action of one being supposed to neutralize that of the other, so that a point placed somewhere between the two, and equally affected by both, would follow the course of neither, but take a path of its own midway between the contrary curves, that is, a straight line. What actually occurs, however, in the case of Watt's contrivance is that this, which may be called the point of attachment, moves not in a straight line but in a curve, bearing a known relation to the varying positions of the two rods, thus describing a figure 8. This eccentric figure, however, is so small, and the consequent variation from the straight line in the working of the

piston or pump-rod so slight as to be easily obviated by packing or other mechanical contrivances, and therefore the oscillation of the piston has been regarded as practically imperceptible, and its action the nearest possible approach to exact parallel motion.

That the motion, however, is not mathematically exact has long since been proved; and though from the time when Watt took out his patent, in 1784, to the date of the present invention, attempts have again and again been made to discover perfect parallel motion, they have always had the same discouraging result, until the question stood a chance of being relegated to the companionship of such mysterious and apparently insoluble problems as the qnadrature of the circle, the trisection of an angle by Euclidean geometry, or perpetual motion. One of the most distinguished mathematicians of this or any other age, Professor Tchebicheff, of the University of St. Petersburg, occupied himself for nearly twenty years, among other researches of vast importance, in efforts to solve the problem of perfect parallel motion, and though he arrived at results which gave greater accuracy than could be attained by Watt's arrangement, every step he took in the direction of a nearer approach to perfection only served to satisfy him that a complete solution of the question was impossible. So firmly convinced was he of this, that he elaborated what seemed to him almost a conclusive proof that such a machine as his exact and mathematical mind demanded was, in the nature of things, inconstructible. Conscious, however, that under some circumstances there was a bare possibility of his demonstration not holding good—that there was, in fact, an imperfect link in his chain of mathematical reasoning—he, to use Professor Sylvester's words, "with praiseworthy caution, held it back until he could succeed in patching up the flaw." Thus the matter stood until quite recently. Last autumn, however, Professor Sylvester received a visit from Tchebicheff, who, in the course of conversation, disclosed the startling fact that not only was the system of proof, which he had been so long building, still incomplete, but that it had been scattered to the winds and for ever disproved by the discovery of perfect parallel motion, first in France some nine years ago, and again more recently in Russia. The undoubted discoverer of this new power—important in its bearing alike on mathematics and mechanical science, is Peaucellier, a young French officer of Engineers, who, true to his vocation as a military topographer, and his early predilection for geometrical researches, seems habitually to have regarded the combination of link-work perfected by him as an instrument rather than an element of machinery, and as such gave to it the name of "Compound Compass." This fact may, perhaps, to some extent account for the obscurity in which the great discovery has been so long allowed to remain; but our surprise that the importance of its principles, and the universality of its application, were not earlier recognized, is in no degree lessened when we learn the circumstances attending its introduction to the world of science, for the details of which we are indebted to the kindness of Professor Sylvester.

While in Paris in 1864 on the staff of the illustrious Marshall Neil, Peaucellier spoke to Captain Manheim, of the French Artillery, Professor of Geometry at the Ecole Polytechnique, about this compass, and the latter, recognizing at once the greatness of the discovery, pressed Peaucellier to make known immediately his contrivance, and especially its principle. This he could not make up his mind to do, but was induced to send a few lines in the form of a question for solution, which appeared in "Terquem's Annals," for 1864, and fully proved that at the time of publication he was in full possession of his discovery.

The question remaining unanswered, Peaucellier was at length prevailed on to allow a communication on the subject of his compound compass to be made to the Société Philomathique of Paris, and accordingly M. Manheim brought it before that body on the 20th of June, 1867. The minutes of this sitting contain only the following notice: "M. Manheim presents considerations on the subject of the compound compass of M. Peaucellier." This was not the effect which Manheim had thought to produce, or to which he considered so important a discovery entitled, and accordingly at the next meeting of the Society he returned to the attack. In his previous communication he had made known the system of jointed rods by means of which a straight line or a circle can be traced, using the geometrical demonstration

which he had discovered; and on the 27th of June he supplemented this by showing how the invention might be applied to the beam engine, fully expecting thereby to create a profound impression, but only to gain, as before, the briefest notice in the minutes of the meeting: "M. Manheim adds fresh developments to his communication made at the previous meeting." From that day forward there was no further mention of the compound compass until one of Tchebicheff's pupils in the University of St. Petersburg, named Lipkin, working in ignorance of what Peaucellier had already achieved, rediscovered his method, and made it known to the Professor, who brought it immediately under the notice of the Russian Government. An account of the results arrived at by Lipkin was shortly afterwards published at Liége, whence it found its way into M. Colignan's treatise on Kinematic, which, though published so late as 1873, refers the invention to Lipkin, and makes no mention of Peaucellier. This account, however, soon reached M. Manheim, who was not slow to claim for Peaucellier the position to which he was indisputably entitled, and which he must long since have won but that his modesty had induced him to accept the unaccountable indifference of the Société Philomathique as the measure of importance which scientific men and the public generally would attach to his discovery. To the credit of his brother officers of the corps of Engineers, it must be said that they were among the first to recognize the immense significance of Peaucellier's contrivance, and to reward him by promotion to the rank of lieutenant-colonel. The Comité de Génie have also awarded him a prize of 1,500 francs for an application of his principle to a topographical instrument.

As we have before said, English mechanicians are indebted for the introduction of the subject in this country to Professor Sylvester, who has adopted it with as much enthusiasm as if it were the child of his own fruitful genius for scientific inquiry, and who has devoted himself to perfecting many novel developments of the principle which should cause his name to be for ever identified with the discovery.

Having said so much about the origin of Peaucellier's system, we will endeavor to describe as clearly as we may without the aid of elaborate diagrams the instrument in which its principle was first exemplified.

Fig. 1.

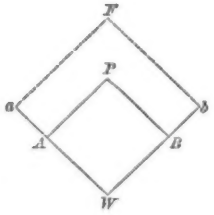


Fig. 2.

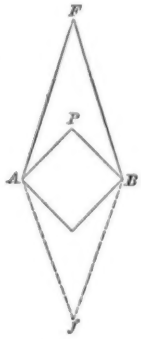
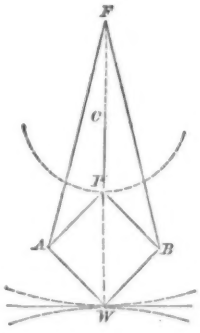


Fig. 3.



In some respects this Compound Compass may be said to resemble the ordinary pantagraph used by topographical draughtsmen; but with this most important difference, that, whereas the initial form of the pantagraph is the combination of two similar parallelograms, one within the other, as roughly indicated in fig. 1., that of Peaucellier's compass consists of two dissimilar parallelograms (fig. 2). In actual practice the links shown by dotted lines are dispensed with in both cases, but this is immaterial in point of theory. Now, if we suppose F in fig. 1 to be a fulcrum, and all the sides simple jointed links free to move round this fulcrum and round each other at their points of intersection, it is sufficiently clear, without geometrical demonstration, that as we press W nearer to F or draw it farther away, so P will move in the same direction, the distances F P, P W, bearing always a proportionate relation to

each other; and if we compel W to describe any curve, P will follow a path directly proportionate to that of W. In the case of fig. 2, however, supposing the fulcrum to remain at the same point and all the conditions of linkage to be similar, it will be found that the distances F P, P W, will no longer bear a proportionate but an inverse relation to each other, that is to say, as P W increases F P decreases, and *vice versa*, the instrument being no longer a proportionator, but an invertor. This we shall hope to make clear in a few words. The annexed sketch, fig. 3, shows, in outline, the compound compass, which, like the pantagraph, is based on a combination of rods, joined by pivots at their points of intersection, and free to move about each other in any direction within certain limits. This primary system of free links Professor Sylvester expressively terms a linkage, in contradistinction to what, in technical language, is a linkwork, when, two or more points being fixed, the value of the different angles in relation to each other is definitely determined, as is, of course, the case in the Paucellier Compass, when complete and mounted.

Following Professor Sylvester's nomenclature, we will designate this peculiar form of linkwork "a mounted cell," and distinguish the different parts thus:—The parallelogram, A P B W, is the rhomb; the external arms, F A, F B, are the connectors; F the fulcrum; and F W the axis of the cell. P, the power-point, and W, the weight-point, are also called the poles of the rhomb. It must be understood that the form of the rhomb and the actual length of the connectors are immaterial, the only conditions being that the latter are equal, and that the three points, F, P, W, lie always in the same straight line whatever the position of the cell may be.

Now, if we suspend the linkage by its fulcrum to any fixed point, and imagine, for the sake of comparative reasoning, the beam, C P, to be absent, and all the joints, A, P, B, W, temporarily converted into rigid attachments, it is clear that these points will all move in concentric circles round the centre, F; loosen the joints once more, and it is equally obvious that, while A and B, being connected by inflexible links to the fulcrum, will still describe round that point the same circle as before, P is left free to move in almost any form of curve, simple or complex, and of varying radius, and that this is also the case with respect to the other pole, W. There is, however, evidently a law which determines the relative positions of the two last-named points; this law being that the nearer P is to the point F, the farther W will be from it, the diamond contracting or opening out as P is moved in any curve not concentric to F; or, in mathematical language, the path followed by W will be inverse to that of P with respect to the point F, these three points lying always in the same straight line, which we have termed the axis of the cell. If by any means, therefore, the point P be made to travel in a determinate course, the curve described by W will be equally definite and invariable. To attain this object we convert the linkage into a mounted linkwork by again adding the bar or beam, C P, to the combination, this bar forming the radius of a circle which P will describe round the fixed point C, then W will follow an inverse path, dependent for its form on the length of the radius C P, or, more correctly, on the position of the centre, C, with respect to F. Now, according to a well-known geometrical law, if the origin of inversion (the point F) lies anywhere inside or outside the circular path of P, W will itself describe another circle. If F be outside the orbit of P then the inverse circle described by W will be also external to F; if, on the other hand, F be inside the orbit, then the path traversed by W will encircle F also; but if, instead of either, the point F lies anywhere within the actual orbit, that is if the circle described by P passes through F, the inverse will be a straight line.

Turning once more to the diagram, let us suppose it to represent a rough working model of Peaucellier's concatenation. Now if the point C be so placed on the axis of the cell that the radius C P is less than half the distance F P, it is evident that the point F will fall outside the circle traversed by P, and it may be experimentally shown that W will describe the external or convex circle, of which an arc is indicated on the figure. Lengthen the radius so that it becomes greater than half the distance F P, then the orbit of P will contain F within it, and W will move in an arc of a circle concave to F, and surrounding it, as indicated by the second dotted curve in the diagram. It requires no mathematical reasoning to show, for it is self-evident, that the curves thus described will grow flatter and flatter

the nearer C is to the actual centre of the line F P; and, as nature never acts *per saltum*, there must be a point in the process of change from one kind of curve to the other, where the inverse path of W ceases to be a curve, either convex or concave, when it theoretically describes two arcs of infinite radius, each looking to a centre infinitely distant—in other words, a straight line. From what has been said it is clear that this cannot happen when the radius, C P, is either greater or less than half F P, and therefore it can only be when C actually coincides with the centre of the line F P. But in this case P in its orbit would evidently pass through F, and, according to the geometrical law already laid down, the inverse described by W would then be a straight line, so that the mathematical law and the mathematical fact coincide, and the result is not merely practically but theoretically perfect parallel motion. Mechanical proof that the path of W is absolutely straight, may be obtained by taking two similar cells and joining them by the weight points. Now if either of them deviated from a straight path, so must the other in the opposite direction—"they would meet but to part like an ill-assorted couple marrying and separating at the church door;" but instead of this they will continue to move without either parting or crushing each other; following together their appointed path, neither swerving to the right nor to the left.

In addition to the forms of cell we have here described, which Professor Sylvester designates a positive cell, he has shown another, termed a negative form, to be equally possible, possessing the same functions, and having some advantages over the positive in economy of space and extent of range. In cells of the negative form the fulcrum lies within instead of outside the parallelogram, but in all other respects the construction is similar.

By his discovery, Peaucellier has placed in our hands the means of converting circular into rectilinear motion with perfect accuracy, without friction, and without any necessity for "packing," or other faulty contrivances, which have been inseparable from every system hitherto devised for the purpose of producing the same result; and the importance of this to mechanicians amounts, as Professor Sylvester has said, almost to a revolution of the principles now predominant in the application of science to the useful arts. Its use is confined neither to the highest nor the lowest branches of industry, but is common to all. It is so simple that it might be economically applied to the working of an ordinary pump handle; so powerful and perfect that the most elaborate mechanical combination to be found among our latest improvements in steam engines, is incapable of producing the same result. We may mention, as the first application of the invention in this country, that a machine, on the principle of a negative Peaucellier cell, is about to be erected in the Houses of Parliament, for the purpose of propelling a large shaft in a lateral direction, the origin of motion in this case being the wheels of a stationary engine, so that here the success of the system will be well tested.

We have been compelled to confine ourselves almost exclusively to a consideration of the invention as a mechanical power, but as a mathematical instrument the compound compass (we may name it according to the inventor's first idea now) is capable of achieving results hitherto beyond our reach, except at the cost of immense labor, and, indeed, with perfect accuracy scarcely attainable at all. Among these is the power to describe curves of almost any radius with absolute exactness, and we have only to mention how this may be made of practical service in laying out railway curves, describing sections of millwrights' work, the modelling of arch voussoirs in masonry, and the forming of moulds for fish-belly torpedoes, to suggest a hundred other cases in which it may be found equally invaluable. Torpedo making is an instance in which the Peaucellier compass would be found specially useful in superseding the cumbersome and costly appliances now necessary to insure the perfect accuracy so essential in the construction of these infernal machines.

Professor Sylvester has, by the combination of a series or train of Peaucellier cells, succeeded in producing some most interesting mathematical and mechanical results. With a mounted double cell of 13 links he is enabled to accomplish what has never been done so successfully before—*i. e.*, a perfectly accurate mechanical description of the conics, and by a linkage of three cells, of course unmounted, he constructs an apparatus for the extraction of the cube root of any number within the range of the machine. All these contriv-

ances point to the immense—we might almost say limitless—application of the principle brought into the world by Peaucellier, but the adoption of which in England we shall owe to the enthusiastic labors of our own distinguished countryman.

TERRESTRIAL ELECTRICITY.

From "Engineering"

In the admirable remarks recently delivered by Sir William Thomson in his presidential address to the Society of Telegraph Engineers, which was printed *in extenso* in our columns, there is one subject which demands more than passing notice. We refer especially to the question of "earth currents"—the bugbear of telegraphists—coupled with other terrestrial phenomena, to which Sir William Thomson has given the name of "terrestrial electricity."

This is a subject in which the President of the Society of Telegraph Engineers has made himself pre-eminent, and his remarks deserve the fullest consideration which can be given to them. The subject embraces the magnetism of the earth, the peculiar but regular variation of the north pole, the phenomena of "earth currents," magnetic storms, and so forth. Sir William says: "That motion of the magnetic pole in a circle round the true north pole has already (within the period during which accurate measurements have been made) been experienced to the extent of rather more than a quarter of the whole revolution. It is one of the greatest mysteries of science, a mystery which I might almost say is to myself a subject of daily contemplation. What can be the cause of this magnetism in the interior of the earth?"

It might well be asked, what can be the cause of the magnetism of the earth? Is it produced by the action of electric currents, or, on the other hand, are these currents produced by the earth's magnetism? We have here a large field for inquiry, and the subject presents to our notice one of the most important points in the marvellous formation of our earth. At present it is a question of hypothesis, a pure mystery, and one to which time alone can give us the true clue.

The automatic observations taken daily at our observatories, especially at the Royal Observatory at Greenwich, show the daily variations of the magnetometers—the horizontal force, the declination, and the vertical force of the magnet—as also the daily variation of the "earth currents." The earth currents are observed by means of two wires, whose terminal points are as near as possible north and south, east and west, the point of intersection of the lines drawn from the earthplates being close to the Observatory. The strength and direction of these currents are photographically recorded, as are also the motions of the magnetometers. These results, traced by the movements of the magnets and the earth currents, will, in the future, be of incalculable value when observations have at length given a clue to the mystery of the earth's magnetism. We propose in an early number to give some account of the Magnetic Department of the Royal Observatory, where the observations of the different magnetometers and of the earth currents are taken.

It is, however, only by the effect of constant observation that we may at length hold in our hands the end of the line which shall lead us finally to the true elucidation of the question. It would be now rash even to suggest an explanation, but we may follow up the points suggested by Sir William Thomson, which will ultimately lead us on to the desired goal. The electric telegraph has now spread its arms over the whole world, and upon the superintendents and operators at the various important stations Sir William relies for obtaining such information as will prove of incalculable value. "Now, if we could have simultaneous observations of the underground currents, of the three magnetic elements, and of the aurora, we should have a mass of evidence from which, I believe, without fail, we ought to be able to conclude an answer more or less definite to the question I have put."

The President puts to the Society of Telegraph Engineers a suggestion which will ultimately bear fruit, and which we trust will soon be acted upon. It is the frequent observation during the day and during magnetic storms of the "potential" of the earth currents passing over tele-

graph lines, whether submarine or overhead. Simultaneous observations of the "potential" of the extremities of a line, taken at regular periods and carefully noted, is what is required.

The question arises, how can this be done? We look upon it as one of the points which will prove to the world the utility of such a scientific body as the Society of Telegraph Engineers, and whether the duty be undertaken by them alone, or in co-operation with the Royal and Meteorological Societies, it is one of paramount importance, and should be at once undertaken.

The Telegraph Engineers are eminently qualified for this duty; their members are skilled in such observations, and they are so widely scattered over the face of the earth that in a very short space of time a small army of observers could be formed for the purpose of assisting in elucidating so interesting a scientific problem. There will, we apprehend, be no difficulty in obtaining the requisite amount of observers, but the instruments of precision required for such purposes are somewhat costly, and it is on this point that the greatest difficulty will be experienced. However, by unity of action and proper representations, we do not doubt but that the instruments will be in due time forthcoming.

The observations of the "currents" which are daily traversing the earth in different directions, of varying strength, and of varying signs, require noting in a most systematic manner, and at regular periods of time. These observations, we consider, should be of two classes, primary and secondary. That is, the observatories for recording these "currents" in various parts of the world should be divided into two classes; the one special, the other general. The instruction as to time being of course universal. The general class of observations would be similar to the general type of meteorological observations, and would embrace notes taken at any telegraph station in the world. By a combined system of action, and with due representation, we believe it possible that all the various telegraph authorities, whether Government or private, would instruct such officials in their service to aid in this great work.

The observations on land lines would consist in noting the deflection on a galvanometer, the direction or sign of the earth current, and so far as can be obtained its "potential." One great difficulty has to be contended with in all land lines, and that is when a magnetic storm occurs, the strength of the "earth currents" becomes so great as to interfere most materially with the working of the line, and sometimes to entirely stop the traffic. We may instance the storm of February 4, 1872, when almost all the lines in Europe and the East were stopped. In such cases the energy of the superintendent and staff is almost entirely directed to the endeavor to get messages through, and so but little time is available for observation. But we still think that on such occasions some most important observations might be taken. Many results have been obtained from various places during some of these magnetic storms, but though from want of simultaneous observation and definite details they have been of no great scientific value, it must be admitted they possess a high scientific interest. In this general class of observation, to insure success, and to obtain valuable records, it would be necessary to issue most explicit instructions, and to supply every observing station with proper forms to be filled up, which, at stated intervals, might be forwarded to the general head-quarters.

It is from what we have termed the "special" class of observers that the greatest result may be anticipated. These observers would naturally be, from the importance of the charge already in their hands, gentlemen of acknowledged scientific skill and electrical attainments. We allude to those electricians who are in charge of the stations at the ends of the various submarine cables, which stretch nearly over the whole world.

By establishing a chain of stations from East to West at the ends of the various submarine cables, and supplying them with instruments of precision, we should obtain a series of observatories of the most important character. Starting from the East, we have Japan, Hong Kong, Port Darwin (Australia), Java, Singapore, thence Madras (where already Mr. G. K. Winter, telegraph engineer of the Madras Railway, has made some most important observations upon the regularity of the daily variation of the "earth currents"). Again, at Bombay, Aden, Suez, Alexandria, Malta, Gibraltar, Lisbon, Falmouth. We have thus a grand chain to England, and from England to America we have Valentia, Newfoundland, St. Pierre, and Boston.

The cables across the South Atlantic to the States of South America could ultimately be added. But the series of observing stations we have mentioned would present a magnificent field for observation.

The observations required would be the potential, the sign and the direction of the earth currents taken with the same regularity as meteorological observation. The instruments required for the purpose would be an accurate and delicate Thomson electrometer, and a Clark's standard cell. The electrometer could always be in constant connection with the cable, as it does not interfere in any way with the working. The standard cell would be necessary for taking the "constant" of the electrometer, which would undoubtedly vary from time to time, so that the results obtained might be noted in "volts" or units of electro-motive force, in order that the various results might be comparable.

We have mentioned a list of 18 stations, as points for observatories, but to commence with, this number might be reduced to 10; this would be necessary in consequence of the expense of a proper electrometer, one fit for the purpose. In many cases, however, the expense might partly be borne by the Submarine Company, as they would then have at their stations a most important instrument, which would be of the greatest use in testing their lines. There is a large field for the further use of such a valuable instrument as a good "electrometer," and it is really worth the while of our electricians to endeavor to make such an improvement in this form of instrument as will materially reduce its cost.

In the interest we have always shown for electrical and telegraphic subjects, we have brought this question before our readers in the hope that the admirable suggestions made by Sir William Thomson will find root, and that as their result the world may obtain such a series of facts and observations as will tend to prove not only the nature and source of "Terrestrial Electricity," but enable us at last to fathom the mystery of the "Earth's Magnetism."

GRAMME'S MAGNETO-ELECTRIC MACHINE.

By W. H. WALENN, F. C. S.

From the "Journal of the Society of Arts."

In a paper that recently appeared entitled "Cheap Electricity," Gramme's magneto-electric machine was alluded to as being one of the most likely means of obtaining this great desideratum. In that paper many of the possible applications of electric force were stated, the nature of electric power was defined, and the main difference between Gramme's magneto-electric machine and the ordinary magneto-electric machine was pointed out by means of a description of the general principle upon which each machine depends. In the present essay, it is intended to describe the action of Gramme's machine in detail, and to set forth the kind of work for which it is most applicable.

It has been said that the great advantage of this machine over all others is insured by a triple combination of circumstances, which the simple construction of the apparatus makes possible. In fact, the production of (1) a continuous current implies that (2) no heating takes place in the bearings of the machine beyond that due to ordinary friction, and that (3) the current is supplied by a minimum of steam power; for the only drawback to the full attainment of the two latter points is the reflex action of any currents that are uncollected or wasted. The almost perfect realization, therefore, of continuity, freedom from skilled attention, and cheapness of working constitute the salient points of Gramme's machine, and give it a position among electro-motors (including galvanic batteries and other magneto-electric machines) which is unique, and has hitherto been quite unattainable.

In practice, the tranformation of one kind of force or affection of matter into another kind of force, is never effected without more or less loss. In the best steam engines less than one-fourth of the heat is utilized as mechanical power; many steam engines only give mechanical power equivalent to one-tenth of the heat used in working them. The transformation of electric power into chemical work is, however, more perfect, for a single battery cell can be made to deposit 96 ounces of copper by the loss

of 100 ounces of zinc; the combining weight of copper being 63.5, and of zinc 65.5, this is more than 98 per cent. of the electric power used. The change of mechanical power into electric force, by the assistance of magnetism, has been hitherto subject to the above described drawbacks, namely, the loss, neutralization, and reflex action of the electric currents, and the heating of the apparatus, and has consequently labored under difficulties from which the continuous current is free; but as no experiments have hitherto been made to ascertain how much per cent. of mechanical force has been converted into electrical force by any of the magneto-electric machines, or, to the author's knowledge, by Gramme's machine, the saving of power and of money which it accomplishes cannot yet be told.

As the facile and definite recognition of an electric current in a given conductor is highly essential to the proper understanding of the action of Gramme's machine, and as many writers on electricity have failed to describe the method of determining this point with ease and certainty, this important point of the subject will be fully set forth. Not only is it necessary to realize the direction of a given electric current in the description of electrical apparatus, but also in the employment of electric force; for instance, if the effect produced by one condition, say the forward progress along a wire, is to heat the point of junction of the two dissimilar metals, then the backward motion of the same current will cool the same junction. In one direction through a chemical solution, the current throws a metal out of the solution on to a given metallic surface; in the other direction it dissolves the metallic surface which it had previously deposited, taking it into solution. In one direction, through the coil of a bar electro-magnet that is vertical, it causes a north magnetic pole to be uppermost; in the other direction, through the same coil, the south magnetic pole will be uppermost. Even scientific men have fallen into error in describing the direction of the electric current evolved from a galvanic battery. Dr. Althaus, in the first edition of his book on medical electricity, announces the remarkable fact (or rather fallacy) "that the direction of the current is different in the ordinary voltaic pile and in the constant batteries." He further states that, "if, however, the metals are plunged into separate vessels, as is the case in the constant batteries, the direction of the current becomes different." The whole of this paragraph is rewritten in the second edition, and the fact of the direction of the current in the instrument being the same in both cases is fully brought out, Dr. Althaus having evidently fallen into error in the first instance, in consequence of the original "pile" of Volta, of the year 1800, commencing with double plates and finishing with double plates; whereas a single negative copper plate for a positive pole at one end of the series, and a single positive zinc plate for a negative pole at the other end of the series, is all that is required. Perhaps the clearest way of stating the direction of the electric current in the galvanic battery, which is the key to all other electro-motors, is mentally to take a single cell—composed of zinc, acid solution, and copper—and to conceive (for the sake of convenience) that the electric force is torn away from between the particles of the zinc plate during its solution by the acid, and that, being set free, the electric force passes across the acid to the copper plate, thence along the wire to the work to be done, and back again to the zinc plate through its conducting wire, thus completing the circuit. If now the word positive be taken to mean the state of giving out electric force, and negative the state of receiving electric force, the following assertions will be true:—The zinc is the positive plate, and the copper is the negative plate. The wire connected to the zinc plate having at its other end a plate in a solution for depositing copper, for instance, and that connected to the copper also having another plate in the same solution at a small distance from the first, the plate connected by wire with the zinc plate is the negative plate, and receives the deposit, that connected by wire with the copper plate is the positive plate, and is gradually dissolved in the solution. If simply the wires be brought from the respective battery plates, and be left free to be employed upon any work that may arise, it therefore comes to pass that the wire from the zinc plate in the battery is called the negative pole, and that from the copper plate the positive pole; for, although the current, in the battery, proceeds from the zinc to the copper, in the connecting wire and through the work to be done, it proceeds from the copper to the zinc. The kind of mental certainty to arrive at, and of figure to be formed in the imagination, in the con-

ception of the ideas I have endeavored to illustrate, is akin to that consummated and to the figure formed mentally when describing the direction of motion of the hands of a watch. We may either say that the hands of a watch move from left to right or from right to left; in the first case we mentally take the upper half-circle by which to describe the motion, in the second case we mentally take the lower half-circle by which to describe the motion. If we always describe the motion of the hands of a watch by reference to the upper half-circle, we must say that they move from left to right; just in the same way, if we always describe the direction of a galvanic current in reference to its passages through the galvanic cell, we must say that it passes from the zinc (as the giving out or positive metal) to the copper, which is the receiving or negative metal. There is this difference, however, between the description of the motion of the hands of a watch and the direction of a galvanic current—that it is scarcely ever necessary to describe the motion by reference to the lower half-circle, but it is very often necessary, when speaking of the work to be done by a galvanic battery or any other electro-motor, to describe the direction of the current by reference to that portion of the circuit which is outside the galvanic cell, and which includes the work to be done. To further elucidate the direction of an electric current, a thermo-electric arrangement of bismuth and antimony may be taken. In this instrument the electric current proceeds from the bismuth to the antimony across the heated junction; the bismuth is therefore said to be positive and the antimony negative. In the frictional machine, generally consisting of a glass plate and a silk rubber coated with amalgam, the current (if it can be called one) proceeds from the glass to the rubber, from the rubber to the earth, and from the earth back again to the prime conductor, thence to the glass plate; the glass plate is therefore said to be positive and the rubber negative. In Armstrong's steam apparatus, called the hydro-electric machine, the issuing steam is positive and the boiler is negative; the current therefore goes from the issuing steam to the boiler, in that portion of the circuit which is internal to the apparatus.

Having stated the exact difference between Gramme's machine and all previous machines that are in practical use, in the article on "Cheap Electricity," it is simply necessary to compare the various mechanical means of applying the principle of augmentation or diminution of magnetic polarity (that upon which all ordinary magneto-electric machines depend), with the only practical means at present known of applying the principle of transition or translation in space of the same force of magnetic polarity, which is the principle of Gramme's machine.

The earliest known remark or notice which has reference to magneto-electricity is to be found in the "Monthly Magazine" for April, 1802. This states that at Vienna it was discovered that "an artificial magnet" decomposed water as well as the voltaic pile. From this point, the progress of discovery and invention divides itself into two parts, for in 1831 Faraday announced two independent facts; one was that the separation of a coiled keeper from a permanent magnet produced an electric spark in a divided portion of the coil; the other was that the rotation of a copper disc between the poles of a permanent magnet generated an electric current from the centre of the disc to the point placed between the poles of the magnet. From the first of these results sprang the magneto-electric machines with to-and-fro currents, which, by the inventive power of Wheatstone, Henley, and others, have been adapted to telegraphic work, without the intervention of a commutator; indeed, they appear peculiarly suited for that class of work in which alternate impulses are required and can be directly utilized. The result with the copper disc is connected with the theory of the Gramme machine, and never had its practical application until M. Gramme's machine was invented. Faraday evidently had a high idea of this, the latter portion of his discovery, for he remarks: "Thus was demonstrated the production of a permanent current of electricity by ordinary magnets."* Foucault searched in vain for the practical method of evolving this current; and Wheatstone neglected to publish his method of working because he did not find it practical.

In its simplest shape, the Gramme machine consists of an electro-magnet, or coiled armature, of an entirely new form, that revolves on an axis between the poles of a horse-shoe permanent magnet, the axis of

* "Experimental Researches," vol. 1., p. 27.

revolution being exactly between the poles, and at right angles to the plane of the permanent magnet. As this electro-magnet is the main point of M. Gramme's invention, it will be well to trace its development from the copper disc of Faraday through certain successive steps. The analogy between Faraday's copper disc and Gramme's electro-magnet is not perfect, even regarding the first as the nucleus which, upon development, might yield the second; for the copper disc was mounted upon a horizontal axis, and its periphery revolved between the poles of a horse-shoe permanent magnet, the horizontal plane of which was at right angles to the plane of the copper disc, the horizontal axis necessarily being at some distance from the magnetic poles; whereas the axis of the Gramme electro-magnet or bobbin is exactly midway between the magnetic poles, and the bobbin is in the same plane as the magnet; but Faraday's arrangement was the first to show that a continuous current could be obtained by the motion of an electrical conductor near to a permanent magnet, or, as it is more distinctly described, in the magnetic field. Another discovery of Faraday's bears more directly upon the exact principle of Gramme's bobbin, although the arrangement only permits of a continuous current (in contradiction to a shock) being obtained for a limited time. About the same date as that of the copper disc experiment, in 1831, Faraday discovered that, during the introduction of a permanent bar magnet into a long hollow coil, an electric current was induced in the coil in a definite direction, and lasted for the time that the magnetic pole, so introduced, moved in the same direction in the coil. This effect is still better manifested, and the analogy with Gramme's bobbin is more perfect, if the long coil contains a soft iron core from end to end, and if this modified arrangement is moved in front of the pole of a permanent magnet, so that successive portions of the axis of the coil become opposite the pole of the magnet. The same result would be accomplished if the coil were fixed, and the magnet moved from end to end of the coil parallel to its axis and always at the same distance from the axis; but inasmuch as in Gramme's plan the coil moves and the magnet is stationary, the former supposition is more directly applicable to the explanation of Gramme's bobbin. Virtually, Gramme's bobbin may be considered as the long coil, with the soft iron core in it, bent round and joined at its extremities, so as to form a continuous annulus or ring. Not only are the extremities of the soft iron core perfectly joined so as to form a complete ring without a break, but the extremities of the insulated wire that forms the coil are soldered together so as to constitute a perfectly closed electric circuit. The axis of revolution of this ring is at right angles to its plane, and passes through its centre. The action of the poles of the permanent magnet upon the soft iron core during its revolution, is to induce two poles of the same name upon that part of the core that is from time to time in close proximity to the pole of the magnet of the opposite name; that is to say, if the north pole of the permanent magnet be uppermost, that part of the core which is from time to time uppermost, and therefore nearer to the north magnetic pole, has induced in it two contiguous south poles. In the same manner it is evident that the lowermost portion of the core, being nearest to the south magnetic pole, has two contiguous north poles induced in it. As the south pole of the core is always uppermost, and the coil revolves, the coil has an electric current induced in its upper half, continuous and in a definite direction. As the north pole of the core is always downwards, and as the circumvolutions of the coil constantly pass this pole in the same direction as they pass the south pole, the electric current induced thereby in the lower half of the coil is continuous, but in the opposite direction to that induced in the upper half of the bobbin, because the opposite magnetic pole is active in inducing this current.

Now comes the question of the direction of the electric current that may be drawn from this machine, in the consideration of which the remarks and elucidations that have already been given, especially those connected with the galvanic battery, will be of essential service. It is simplest, in the first instance, to consider the electric current in the upper half of the coil totally independent of that in the lower half of the coil. An apparatus, presently to be described, is applied to the bobbin, so as to collect the current at the two points in the horizontal diameter of the bobbin that separate the constantly changing upper half from the lower half; the definite direction of this current in the upper half depends

upon the polarity induced in the core at its constantly changing apex (south polarity), upon the direction of rotation of the bobbin, and upon the direction in which the insulated wire is wound, whether as a right-handed or as a left-handed screw. If the ring be driven in the direction of the hands of a clock (from left to right), and the coil be a right-handed screw (proceeding from right to left), having a south polarity induced in it, the electric current will be from the right hand of the diameter of the ring to the left. If a galvanic cell be supposed to be in the place of the upper half of the ring, the zinc plate of that battery would be to the right hand, and the copper plate to the left. In the lower half of the ring the analogous galvanic cell would also have its zinc plate to the right hand and its copper plate to the left. This is seen more clearly by the reader, if he constructs a sketch according to the above description and results from the fact previously alluded to, namely, that the current from the lower half of the ring is in the reverse direction to that in the upper half of the ring. When the sketch suggested above is made, it will be realized, that if two stationary wires were maintained in rubbing contact with the metal of that portion of the coil which is constantly passing the horizontal diametrical points above alluded to, one wire being in contact with one extremity of the diameter, the other with the other extremity, these wires would conduct away both currents in the ring, and as these currents always continue in the same direction, and never change either their absolute or relative direction, there is no necessity for a commutator, or pole-changer in the ordinary sense of the term, but only for rubbing contacts. To clearly understand that both the currents are able to be collected in the way above indicated, although they are neutralized in the continuous circuit of the ring, it should be realized that, thus wrought out, the arrangement is equivalent in electric action to deriving an electric current from two galvanic cells that are virtually two halves of the same cell. To illustrate this in a lucid manner by sketching, the direction of the currents may be indicated by arrows, according to the above description, in connection with a circle that represents, in the fashion of a diagram, the centre line of the ring, the two conducting or polar wires being placed at the extremities of the horizontal diameter. As plates of a similar name will be seen to be metallically connected, if the analogous galvanic cells are placed in this diagram, it will be easily understood that the galvanic analogy is enabled to be carried as far as that, by supposing the cells to approach each other and then by removing the walls of each cell (all of which supposition may be carried out by successive sketches on paper), the arrangement is seen to be virtually the same as that of a single current proceeding from a single cell in the direction indicated by the plates of that cell.

The method of establishing the rubbing contacts merits a separate description. That rubbing contacts are essential is evident from the fact of its being necessary to take the electric current from those portions of the moving coil that successively arrive at two opposite points of a fixed horizontal diameter. This can only be done by fixed contact pieces placed respectively at the extremities of the diameter of another circle concentric with the shaft on which the bobbin rotates. To denude a portion of the coil of its insulating material, at the place where the rubbing contacts could conduct away the current (a circle of more or less breadth, concentric with the ring), would be mechanically impracticable, for the coils are of fine wire, they overlap, and they are not in their external portions at all regularly disposed, at least not sufficiently so to be treated in this manner. It is, moreover, highly necessary that the contact pieces in connection with the coil, and therefore movable, should be able to bear friction. This result is best accomplished by means of a cylindrical *frotteur* or rubber, in connection with the axis of the bobbin, the frotteur being fixed on the axis at a convenient place for the stationary contact pieces to bear strongly upon its cylindrical surface, and for the wires from certain divisions of the coil to be brought for the conveyance of the whole of the current of the machine to it. The frotteur itself consists of a cylinder of hard-wood, or other non-conducting material, driven tightly on the axis, and carrying on its surface separate and distinct rectangular plates of metal, placed at equal distances upon its circumference. The plates are securely fixed with their longest dimensions parallel to the axis of the cylinder. Although the coil of the annulus is perfectly continuous, certain offshoots or branch wires are taken from it

at equal intervals to the various plates of the frotteur. There may be twelve branches, or as many as forty, according to the size of the machine and the kind of work it has to do. The stationary rubbers may consist of wheels at the extremity of standards. Each wheel is pressed, by springs or otherwise, against opposite points in the horizontal diameter of the frotteur, and its standard is furnished with a binding screw for holding the conducting wires of the apparatus. One binding screw attaches the positive wire to the machine, the other the negative wire.

Undoubtedly, the principal applications of the electric current from this machine are to the electric light in its various modifications, and to the deposition of metals in some cases from their ores. The separation of copper from its ores is waiting for a cheap electro-motor to make it a successful manufacture. The singular aptitude of Gramme's machine for manufacturing purposes on a large scale lies in its constancy as well as its continuity of action; as long as the motive power rotates the machine at the same speed, the current from it is the same in power, and the speed of rotation need not be great. There are some uses of the machine which have still to be tested; amongst them may be mentioned increasing the traction power of locomotives by electro-magnetic attractions, the firing of mines, and the treatment of iron, in a hot state, by magnetic induction.

ON THE MECHANICAL PRODUCTION OF COLD.*

The author defined the mechanical production of cold to be the removal of heat from a body without the intervention of a colder body, by a continuous circle of operations. Any arrangement for effecting this was merely a heat engine, whose temperature of absorbing heat was lower than its temperature of rejecting heat, the motive power in this state of things being negative. An air engine was the type of all refrigerating machines in which the medium used was incondensable gas. A steam engine with a surface condenser might be taken as a type of those in which this medium was a vapor or condensable gas. Harrison's ether machine was the best known of this type.

The author's attention was first directed to this subject when manager of the paraffin oil works of Messrs. Young, Meldrum, and Binney, where a large quantity of paraffin had to be extracted from the oil. To effect this it was necessary to cool the oil in which the paraffin was contained in solution, to a temperature of from 35 deg. to 40 deg., in order that the paraffin might crystallize and be separated. When, from the constantly increasing size of the works, it became impracticable to cool this oil by exposure in cold weather, an ether machine was procured, which did good service and overcame the difficulties for a year. As at the end of that time the machine was found to be too small, and as in use it not only required a great deal of care, but had been attended with several narrow escapes from fire, it was considered desirable to attain the same end without the employment of a volatile and inflammable fluid. Air was selected as the medium, and the author was requested to devise the means for making it available.

The experiments were commenced on a small scale. At first air was compressed into a receiver, and allowed to expand by driving a small engine—a plan which had been before proposed and tried, but offered little encouragement. The next trial was with an apparatus similar to Stirling's air engine, with which, after many modifications, mercury was frozen. This apparatus consisted of a cylinder of thin tin plate, and a piston of the same material soldered air-tight. The ends of the cylinder were cones, with their apices looking inwards. The lower cone was kept full of water to carry off any heat that might be formed, and into the upper one was placed the substance to be cooled. The piston was hollow, sliding nearly air-tight in the cylinder, the ends being conical, to fit the ends of the cylinder, and connected at their apices by a cylindrical opening filled with layers of wire gauze. Through this opening, when the piston was moved up or down, air passed freely from the space above the piston into the space below, and *vice versa*, traversing on its way the layers of gauze of which the regenerator was composed. The lower end

* From a paper read before the Institution of Civil Engineers, by Alexander Kirk.

of this cylinder was connected by a pipe to a cylinder and piston, so that, by moving the latter up and down, the whole of the contained air was alternately compressed and expanded. The piston was moved by a crank, and on the same shaft there was an eccentric at right angles to the crank, by which the piston containing the regenerator was moved up and down. The crank and eccentric were so placed that while the piston was compressing the air in the cylinder, the piston containing the regenerator was at the top of its stroke, and the air in this cylinder was compressed in the space between the piston and the conical bottom containing cold water, by which the heat of compression was removed from this portion of the air. When the piston by which the air had been compressed was at the bottom of its stroke, the piston containing the regenerator was moving rapidly downwards, and the compressed and cooled air was passing through the regenerator, from the lower space into the space between the piston and the upper conical end of the cylinder. While the piston containing the regenerator was in this position the piston by which the air had been compressed moved upwards, and the air in contact with the upper cone expanded, abstracting heat from the contents of the cone, whatever they might be. The regenerator prevented heat passing with the air from the hot chamber to the cold.

As the regenerator formed an essential part of the apparatus, and much of the efficiency of the machine depended on its working properly, the author made a series of experiments to ascertain what quantity of heat would be conveyed by air through regenerators of various constructions and proportions. Two kinds were tried; one of wire gauze in layers, the air entering at right angles to the sheets, and another of sheets of metal divided into strips and placed edgeways to the current of air, which thus passed along the surface of the plates. The apparatus consisted of a cylinder, in which a piston was moved backwards and forwards, causing the contained air to pass at each motion of the piston through a hole in the cylinder containing the regenerator to be tried. One end was kept at a temperature of 212 deg., and in contact with the other there was a measured quantity of water, of which the rise in temperature showed the amount of heat that had passed with the air through the gauze. In the best results, the air, when of atmospheric density, in travelling from the cold end to the hot end and back again to the cold end, was found to have become warmed 0.0162 deg. for each degree of difference of temperature between the hot and cold sides of the regenerator; and with air of 100 lbs. pressure per sq. in. above the atmosphere the rise of temperature was only 0.00421 deg. for each degree of difference. From these experiments the author drew the following conclusions:

(1) That the efficiency of the regenerator increased nearly in proportion to the density of the air, but in a somewhat slower ratio; and that the efficiency of all surfaces for heating and cooling the air would increase nearly as the density of the air passed over them.

(2) That it was sufficient to use one layer of gauze for each 3 deg. difference of temperature between the two sides of a regenerator.

(3) That in a regenerator the surface exposed to the action of the air only was of value, the proportion of weight of regenerator to weight of air passed through it being of no value.

In the large machine as actually made, the principle of action was precisely the same as in the model. The compressing and expanding cylinder was double-acting, each end being connected with a cooling cylinder. The piston of the compressing cylinder was worked direct from the piston of a steam engine, and the pistons of the cooling cylinders were connected to each end of a beam, and were worked by an eccentric at right angles to the crank. The action of this machine was illustrated by a diagram; the motion of the pistons being represented by curves, the ordinates of which showed the volume of air in the several compartments of the machine at each part of a revolution. In these machines the air contained might be at any pressure, the efficiency of the machine and its capacity for work increasing with the pressure. The ordinary working pressure was from 100 to 120 lbs. (maximum) per sq. in. To maintain this pressure and to make up loss by leakage, there was a small compressing pump drawing its supply of air through two boxes in succession, each filled with chloride of calcium. It was necessary to keep all moisture out of the machine, as, if the air pumped in were damp, the extreme cold of the expanding air caused it to be con-

densed and to be deposited as snow, chiefly in the upper layers of the regenerator. Besides enabling the use of all volatile and dangerous fluids to be dispensed with, which was the object aimed at in adopting this machine at Bathgate, experience showed that but few repairs were required, owing chiefly to the absence of valves, and to the possibility of using cupped leather packings. The repairs were in amount and kind such as were required in a steam engine, and were equally within the skill of an engine fitter. The machine at Bathgate had worked night and day since the year 1864.

The author next described a modification of this machine, adapted to work with moist air, and capable of being constructed on a large scale, without the difficulties which attended the manufacture of extensive cooling surfaces in the former machine. It differed from the one just described in the corrugated plates being dispensed with, and the water or brine to be cooled, and the water to remove the heat of compression, being injected amongst the working air. Consequently the interior of the machine required no lubrication by oil, and there was no need to keep the air dry. This machine consisted essentially of two cylinders placed side by side, each containing a double acting plunger, connected to a crank fixed on a revolving shaft, at any angle between 180 deg. and a right angle, but the author preferred them to be from 135 deg. to 120 deg. apart. These cylinders were connected at each end by a large open passage, containing a regenerator, through which, on the plungers being moved, the air could pass freely from one cylinder to the other. The water to be cooled was forced in by a pump and allowed to flow down one end of the regenerators, while the water used to remove the heat of compression was forced in and allowed to flow down the other end. The water thus flowing constantly into the machine escaped through valves whose opening was regulated by a float. It was then explained by a diagram, whose ordinates showed the volume of air in each compartment of the machine at every point in a revolution, how two plungers, arranged as above, performed the function of the three pistons employed in the dry air machine, one piston moving up and compressing while the other was nearly stationary at the end of its stroke, both pistons moving opposite ways and shifting the compressed air into the other cylinder, that piston receding and expanding the air while the first piston was nearly stationary at the end of its stroke, and then both moving opposite ways and shifting the expanded air back into the first cylinder. The first cylinder was hot and the second cold, and being double-acting the same operations were performed at each end of the same cylinder. This machine was the first constructed, and might be improved; the mechanical friction was too great, and the construction of the regenerator was not what could be wished. By a rearrangement of the machine the friction had been much reduced. The regenerators now procured could not at first be obtained, and reliance had to be placed on a somewhat imperfect one of sheet brass. In the works where this machine was used these imperfections were of incomparably less importance than the power of its doing work regularly, with little trouble to any one, and with perfect safety even in careless hands.

The two machines described—the wet and the dry air machines—had each a value of their own. The dry air machine was capable theoretically of producing any degree of cold, while in the wet air machine the range was limited to about 22 deg. when using brine, but within that range was to be preferred. With one dry air cooling machine to abstract at a very low temperature the heat rejected in a second machine, temperatures might be maintained lower than any yet reached, and thus an important instrument in physical research would be put in the hands of the investigator. The great advantages of the wet air machine, which must secure its adoption in all cases where the range of temperature was limited, were that the temperatures of the air and of the water were nearly equalized; no oil was required in the cylinders, and it was not necessary to dry the air previous to its admission into the cooling cylinder. The importance of this was well illustrated by the trouble in getting ordinary enginemen to attend to so simple a matter as fuzing chloride of calcium. This elementary step from the domain of ordinary mechanics to the domain of chemistry had, particularly abroad, given more trouble than all the rest of the machine put together. After suggesting that cooling by expansion would probably be found a more effectual means of drying air than either chloride of calcium or sulphuric acid, the author, in conclusion,

gave the results of three trials of these machines

(1) Of the dry air machine, made at Bathgate in 1864:—Diameter of cooling cylinders, 36 in.; stroke 2¾ in.; diameter of compressing cylinder, 15 in.; stroke 30 in.; pressure of air in one cylinder by gauge, 100 lbs. maximum, 46 lbs. minimum; pressure of air in other cylinder, by gauge, 110 lbs. maximum, 52 lbs. minimum; revolutions, 66 per minute; power spent in driving, including friction, 23 horse power; quantity of cooling water per minute, 4.3 gallons; temperature of inflow, 62 deg.; temperature of outflow, 94 deg.; quantity of brine cooled, 6.7 gallons per minute; temperature of inflow, 32 deg.; temperature of outflow, 23.5 deg.

(2) Trial of the wet air machine, June 24, 1871:—Diameter of hot and cold cylinders, 36 in.; stroke 36 in.; diameter of barrel of hot and cold water pumps, plunger, and bucket, 6 in.; stroke, 6 in.; revolutions per minute, 35; power by diagrams from steam engine, 37 horse power; power by diagrams from air cylinders, 26.3 horse power; quantity of cooling water per minute, 20.3 gallons; temperature of inflow, 62.25 deg.; temperature of outflow, 81 deg.; quantity of fresh water cooled per minute, 20.6 gallons; temperature of inflow, 61.25 deg.; temperature of outflow, 47.25 deg.

(3) Trial of the same machine in the ordinary course of its work, cooling paraffin oil at the Oakbank Works, Midcalder, December 14, 1872:—Revolutions per minute, 34; power from diagrams of steam cylinders; spent in driving, including friction, 25 horse power; quantity of cooling water, per minute, 18.55 gallons; temperature of inflow, 67 deg.; temperature of outflow, 73 deg.; quantity of brine per minute, 13.05 gallons; temperature of inflow, 37 deg.; temperature of outflow, 28.25 deg.

Unfortunately the exigencies of the work required the quantity of brine to be reduced to nearly one-half of what it ought to have been. Thus, the screens were imperfectly washed, the air imperfectly warmed, and the general efficiency of the machine was somewhat reduced. In the above experiments the water was measured in tanks erected for the occasion.

If these machines were perfect and worked without friction, the results for 1 lb. of air would have been for one revolution:

In the dry air machine: foot pounds to drive machine, 1179.993; rejected heat, 7.12 lbs. of water heated 1 deg. Fah.; absorbed heat, 5.59 lbs. of water cooled 1 deg. Fah.; temperature of rejected heat, 587 deg. absolute; temperature of absorbed heat, 461 deg. absolute.

In the wet air machine: foot pounds to drive machine, 756.359; rejected heat, 6.68 lbs. of water heated 1 deg. Fah.; absorbed heat, 5.28 lbs. of water cooled 1 deg. Fah.; temperature of rejected heat, 561 deg. absolute; temperature of absorbed heat, 476 deg. absolute.

Applying these results to the trial of the dry air machine, and the second trial of the wet air machine, as the temperatures assumed above agreed with what probably was the temperature of the air in these trials, the perfect results, without friction, etc., ought to have been:—

In the dry air machine: Indicated horse power, 7.8; rejected heat, 1,409 lbs. of water heated 1 deg. Fah. per minute; absorbed heat, 1,106 lbs. of water cooled 1 deg. Fah. per minute.

In the wet air machine: Indicated horse power, 7.8; rejected heat, 2,271.2 lbs. of water heated 1 deg. Fah. per minute; absorbed heat, 1,795.2 lbs. of water cooled 1 deg. Fah. per minute.

COMPOUND ENGINES.

By A. MALLET.

Translated for Van Nostrand's Magazine.

(*Continued from page* 304.)

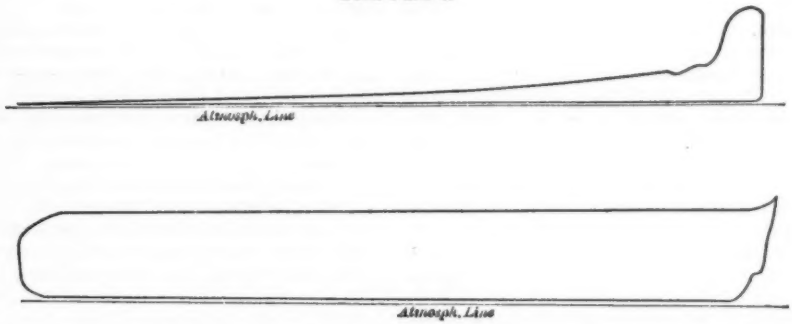
We shall now investigate the causes of the physical superiority in the action of compound engines over those with a single cylinder.

These causes are two in number: The first, which is common to all engines of this class, is due to the fact that the difference of extreme temperatures in each cylinder is less, and that the interior condensation is much diminished. The second, which is peculiar to engines with an intermediate reservoir, is due to the partial removal of

the water from the steam which held it in suspension at the time of its leaving the first cylinder; so that the water does not pass, in a liquid form at least, to the second cylinder.

For the better comprehension of these effects, it is necessary first to examine what takes place in single-cylinder engines. Suppose an engine of this kind acting expansively; the steam is admitted during, say one-fifth of the stroke. Then the piston moves by virtue of the expansion, and the pressure diminishes in a certain ratio with the increase of volume, until the end of the stroke. As the temperature of the steam diminishes with its pressure, a contraction takes place in consequence of the cooling, which acts at the same time with the expansion to diminish the pressure; and we perceive that if the steam receives no heat during its expansion, the pressures will diminish more rapidly than by Mariotte's law. But, on investigation of the action of expanding engines without cylinder envelope, we find a different condition of things. We have taken a number of indicator diagrams from a non condensing engine, into which admission took place only during very small fractions of the stroke, varying from $\frac{1}{40}$ to $\frac{1}{8}$. Besides, the actual expansions were much less because of dead space; the correction reducing the apparent expansions from 40, 20, 13.33, 10 and 8 to 14, 10.5, 8.04, 7, 6 volumes.

FIGS. 3 AND 4.



The figure (3) shows the diagram from an engine with actual expansion of 14 volumes. The initial absolute pressure being 2.75 atmospheres, the tension at the end of the stroke, by Mariotte's law, should be considerably below the atmospheric pressure. The diagram shows the contrary. The pressure, which decreases rapidly near the post, afterwards approaches the horizontal line, and at the end of the stroke is considerably above the atmospheric line. This is due to the vaporization of the water in the cylinder during the period of expansion, which furnishes a supplement of steam whose tension is added to the primitive tension.

At first it seems that it is an advantage that the work obtained is greater than that due to Mariotte's law; but we must count the cost, and it is easy to show that it costs as much or more than the work of full pressure during the entire stroke, so that all advantage of the expansion is lost.

By calculation of the area of the curve and of the mean ordinate, we shall find the mean effective tension of the steam to be 0.236 kil. per square centimetre. The cylinder has a diameter of 0.200 m., a stroke of 0.40 m., 30 strokes per minute; the work on the piston is 29.2 kilogrammetres. The volume of steam in the cylinder at the instant of closing of the admission port, dead space included, is 0.942*l*. This weighs (at a tension of 2.75 at.) 1.50 gr. per litre; that is, 1.163 gr. for 30 strokes per minute, corresponding to 4,547 per hour, or 11.65 H. P. of sensible steam acting on the piston.

If we now take a volume corresponding to $\frac{1}{10}$ of the stroke, and, assuming that the steam is in a saturated condition in the cylinder, apply to this volume the weight per litre corresponding to the observed pressure, we find at this moment in the cylinder a weight not of 1,263 gr., but of 1,410 gr.; at the middle of the course it is 4,837 gr. At the end it is still less, but at this point observation becomes more difficult because the

pressure comes near the atmospheric line. We assume the figures 4,837 gr., which correspond to a sensible expenditure of 47 kilog. of steam per H. P., hourly; *i. e.*, 4 times the amount found above.

Referring to figure answering to the admission for the whole stroke, we find that the mean ordinate of mean effective pressure is 1.56 kil., giving for 30 revolutions a work on the piston of 196 kilogrammetres, or 2,615 H. P. The volume of steam which fills the cylinder at the end of the stroke is 12.56*l*.; which, at a pressure of 2.95 atmospheres, gives 18.84 gr., or 67.824 kil. hourly, or 26 kil. per H. P.

As there can be no other steam in the cylinder, we must conclude that the engine uses less at full pressure than when acting with full expansion, a fact long ago verified.

The presence of the great quantity of steam in the cylinder, can be explained only as due to vaporization during the period of expansion of the water contained in the cylinder, which is caused by diminution of pressure, and at the expense of the heat of the metal. But from what source does this water come? In the case under consideration the water was supplied by a tubular boiler; but the engine went very slow and did very little work.

As the dimensions of the boiler corresponded to a performance 15 or 20 times as great, it is difficult to admit that any considerable portion of the water was held in suspension in the steam. It was almost entirely due to the condensation at the admission port. The steam meets the surfaces, walls and ends of the cylinder, the piston and the rod, all of which are at a lower temperature, and partly condenses, while it raises the temperature of the metal. To raise 10 kilog. of metal 10 deg. requires $10 \times 10 \times 0.15$, or 15 units of heat, answering to a condensation of about 30 grammes of steam. Hence, at the beginning of the stroke there is a certain quantity of water; it is this which vaporizes as soon as the pressure at the admission port diminishes, by absorbing the heat of the walls of the cylinder and that of the piston, a heat which is lost by escape or by transfer to the condenser. The cooled metal then demands from the steam just arrived from the boiler a fresh quantity of heat, acting as an agent to exchange between boiler and condenser. This explains the fact often noticed, that in condensing engines, having cylinders without jackets it is more difficult to effect a vacuum with complete expansion than with full steam.

It is to be observed that the elevation of the temperature of the walls of the cylinder by condensation does not take place instantaneously, any more than does the vaporization that attends expansion. Time has its part in the phenomenon. In engines of slow action the loss of heat is much greater than in those of more rapid movement. The engine in our own experiments was under the most unfavorable conditions; acting without condensation, at full expansion, slowly, and at a low pressure.

The office of steam jackets is to keep the walls of the cylinder at a constant temperature, so as to prevent the presence of water in the cylinder and the resulting inconveniences. A certain quantity of heat is lost, corresponding to the condensation in the jacket; but as the pressure in the jacket does not vary, this condensed steam will remain in the condition of water, or will be expelled by the clearing valves; it will not pass back into the state of vapor while absorbing the heat, as would be the case if it had been condensed in the cylinder. This is the true statement of the action of jackets: *they maintain the heat in the cylinder and cause condensation to take place in the jacket where the pressure is constant, and not in the cylinder where it is variable.*

The jacket does not always prevent the formation of water within the body of steam, because of very prolonged expansions due to cooling and dilatation. We shall find it possible to avoid these consequences.

The following observations are of interest:

(1) We note the little efficacy in the action of jackets of wood, felt, polished brass, etc., which resist only cooling from without.

(2) It is easy to show that little would be effected by replacing the steam in the jacket by the heated gases of combustion, as has been attempted in some engines (sometimes the interior cylinders of locomotive engines are placed in the smoke chest).

A cubic metre of steam at 5 atmospheres weighs 2,600 kil., and by condensation may lose 500 heat units per kilogramme, or 1,300 per cubic metre. A cubic metre of gas from combustion, at a temperature of 350 deg. represents 0 66 kil., giving $200 \times 0.25 \times 0.66 = 33$ heat units.

To replace a layer of steam a centimetre in thickness would require a layer 40 centimetres thick, of heated gas (assuming that the conductibility is perfect), or 40 square metres to replace a square metre of heated steam.

(3) In the old engines the steam from the boiler circulated in the jacket before entering the cylinder. It is easy to see that this would cause steam to pass into the cylinders containing water in suspension, which would cause a clear loss of heat in case of expansion; then this water would remain in the jacket without disadvantage. A special pipe should always be used through which to pass the steam into the jackets.

What has been said regarding the jackets applies equally to the cylinder ends and to the pistons. The importance of regarding the latter is great in engines of short stroke, in which the diameter is $2\frac{1}{2}$ times or more than the stroke. In these engines the ends are always heated; and pistons are heated by means of grooved rods and other devices.

Nowadays cylinders and their jackets are generally of the same coating, in order to avoid complex and delicate adjustments. Hence serious difficulties in construction. Perkins, in the engines of the steamer Filga, substituted for the jacket a serpentine iron tube sunk into the cylinder. In this tube the steam circulates. This compels an increased thickness of the cylinder. But the weight need not be much greater than with a jacket, and the construction is easier.

We return to two-cylinder engines. Notwithstanding the real efficacy of steam jackets, still it is certain that there is always more or less condensation of water during expansion. This is necessarily proportional to the extreme differences of temperature to which the cylinder is subjected, as well as to the extent of cooling surfaces.

In double-cylinder engines, especially with intermediate reservoir, this difference of temperature is reduced for each cylinder. If we suppose a pressure of 5 atmospheres, corresponding to 152 deg., an intermediate pressure of 2, corresponding to 120 deg., and a final pressure of 0.50, corresponding to 81 deg., the difference in the first cylinder will be 32 deg., in the second, 39 deg. With a single cylinder the difference would be 71 deg.

We shall find that the total condensation will be considerably diminished. Suppose the ratio of volumes of the two cylinders to be 2, 5, the first being 0.78, its total cooling surface is 4.70. The volume of the large cylinder being $0.78 \times 2.5 = 1.95$, its cooling surface is 8.86. We have then

$$4.7 \times 32 + 8.86 \times 39 = 495.$$

A single-cylinder engine of the same work and the same expansion should have the dimensions of the large cylinder. In this case we have

$$8.86 \times 71 = 629.$$

The advantage in favor of the double-cylinder engine is 21 per cent. It is so real that, as mentioned before, jackets are sometimes dispensed with in compound engines, when the expansions are not great. It is possible also in engines with intermediate reservoir, which have the special advantage, that the water held in suspension at the time of leaving the first cylinder is deposited in the reservoir and does not pass into the second cylinder. It would seem that it always has been observed that the intermediate reservoir produces much water, for Zander, in his patent, mentions the use of a float valve to discharge this water. The intermediate heater vaporizes this water and makes it do work again in the large cylinder.

The following are the conclusions which we think can be drawn from our investigations:

(1) The usefulness of a steam envelope is incontestable, being greater as the differences in temperature increase, so that jackets are more advantageous for condensing than for non-condensing engines, for great expansion than for slight, for single than for double-cylinder engines. But when expansion is considerable, the jacket is not sufficient.

(2) Engines of two cylinders have a decided superiority over those with one, so that for moderate expansions, steam jackets may be dispensed with.

(3) The compound engine, which we have called the Wolff, has advantages over the ordinary Woolf engine, because the dead spaces have less influence, and because the steam that has worked in the first cylinder can be there separated from the water, so as to work better in the second cylinder. Again, the small cylinder is less exposed to interior cooling, and it is less necessary to employ the steam jacket.

These facts seem very simple, yet they are often misconceived. For example, we read in the work of a distinguished author, as follows: "The means by which economy of steam is attained, consist, while using mean or high pressures, (1) in superheating the steam; (2) in employing long expansions, either by Woolf's method, or directly. This requires, all other things being equal, less complicated apparatus, and it is considered efficient at least as regards the utilization of the steam. In land engines, where space is of little account, some builders propose to make use of expansions of 0.95 (20 volumes). In all such cases the cylinders have envelopes. But the use of jackets with circulation of steam is to be avoided."

This was written in 1866. We think that, in view of a great number of facts and of the general use of the compound engine, the author should modify his conclusions.

The Bulletin of the Industrial Scientific Society of Marseilles (1873) contains this note upon steam jackets, by Stapfer:

"Steam jackets are a costly addition, which only apparently increase the power of an engine. They seldom last more than two years, unless with the greatest precaution. Indeed, there are few engines in which they are not much obstructed. Of course, I do not refer to locomotives whose cylinders are inside the steam chest or in the smoke box, but only to return-water jackets. It is obvious that by placing the cylinder in an atmosphere of waste gases at 300 or 400 deg., a very appreciable quantity of heat can be utilized. But these are conditions seldom realized, and they belong rather to the construction of the boiler."

We can here only refer the reader to what has been said above concerning the real value of the direct action of the gases of combustion. They can be turned to account only by the aid of considerable surfaces. Those of the cylinders and the intermediate reservoir are not sufficient.

The heat of the gases of combustion has often been employed to reheat the steam in its passage from one cylinder to the other. Normand has made use of a tubular apparatus set in the smoke box. This was applied to his first engines and is found in his latest, as in the Ville de Brest and the Belgrano.

Stapfer says that jackets use too much steam; and to a certain extent without useful result, by superheating the steam at the end of its course in the large cylinder, when it is about to pass to the condenser. This objection has probably in some cases caused the suppression of the jacket of the large cylinder. Though the action of the jacket may be very efficient in vaporizing the water of condensation, especially on the cylinder walls, it is of little effect in heating the steam, the conductibility of which is very feeble. If, then, there is a superheating of steam, it occurs only in immediate proximity with the walls, and only when all the water has been vaporized. This vaporization and the effect of the jacket are of no account while the piston is driven by the steam. That the loss should be appreciable particular conditions are necessary; for example, that the escape should take place during a considerable portion of the stroke.

In engines of rapid action, the transmission of heat would not be sufficiently rapid. Stapfer seems to perceive this fact, for he says: "Steam jackets would be good for engines of slow action, in which heating takes place slowly."

The objection regarding the waste of steam by the jacket, made even when it is proven that this helps to avoid a greater waste, holds true in a degree only. But it is worth while to reduce it as much as possible. We think this can be done by employing the gases of combustion, not in directly heating the cylinders, but in generating steam to feed the jackets. The apparatus might consist of a small group of tubes at the base of the chimney where a portion of the water condensed in the jackets would collect, either by the action of its own weight or by contrivances easily adjusted.

The water would always be the same, and not coming into contact with impure substances, it would remain free from the obstructions.

The steam generated in this small boiler heated by the gases of combustion would serve only to heat the cylinders, and not at all in the direct production of motive power; so that it would be possible to supply the heat necessary for the jackets without cost.

Attempts have been made to utilize the heat held in the steam at its discharge from the cylinder by vaporizing a liquid more volatile than water, and to have this vapor act upon a second piston. By this means more work would be realized without employing much of the expansion of the first cylinder. These engines, invented by Dutrembley, who has made a great number of

them, are engines of graduated pressure (*pressions étagées*). It is easy to show that the same result is obtained more simply by utilizing the expansion of the steam in successive cylinders.

Suppose a kilogramme of steam leaves the first cylinder and enters the ether condenser at 80 deg. or at one-half an atmosphere. This steam can supply 550 heat units and will vaporize about 3.5 kil. of ether at 3 atmospheres of pressure, or 440 litres of vapor. These cannot be in the ether condenser less than an atmosphere of resisting pressure; for the boiling point of ether is 38 deg.; so that expansion cannot be more than 3 atmospheres to 1.

The work of the ether cylinder will be

$$0.440 \times 3\ (1 + e \log.\ 3) - 1.32 \times 1 = 1.45.$$

If, instead of using the steam to vaporize ether, expansion is effected in a second cylinder, nearly up to the condenser pressure, it could be raised from 0.5 to 0.2 or 2.5 volumes; even supposing the most unfavorable conditions, as a tension of half an atmosphere at discharge from the first cylinder; which would imply a previous considerable expansion.

A kilogramme of steam at half an atmosphere, represents 3.200 mc.; hence the work would be

$$3.200 \times 0.5 (1 + e \log.\ 2.5) - 8 \times 0.2 = 1.47.$$

The work is theoretically the same as that with ether; but in fact it would be more considerable, and it is obtained more simply, without the help of a dangerous fluid, without complicated vaporizers and condensers, and other disadvantages. It is but a slight advantage that the ether cylinder would have a volume of 1.32, while that of the compound engine has a volume of 8.

A disadvantage in the use of ether is, that though the boiling point is low, its tension in the condenser is high, so that what is gained in one way is lost in another. Besides, its vapor has considerable density.

Combined vapor engines have given good results when comparison was made with engines in which steam has been badly utilized. They gave splendid results when their consumption was 1.50 kil. per H. P., as compared with 2.25 to 2.50 kil. of steam engines. Nowadays, a kilogramme per H. P. is realized with much simpler means. Still it would not be fair to forget that ether engines have rendered important service by familiarizing us with the use of surface condensers. The majority of these engines, after the use of ether was given up, have been worked as steam engines with the use of ether vaporizers and condensers as surface condensers.

V. Our investigations naturally lead to the question whether by increase of pressures and expansions indefinite improvements may be realized; or, as Siemens has said in his report to the Institute of Mechanical Engineers, whether, in the course of ten years, we may not hope for a reduction of 50 per cent. in consumption.

We must first say a few words of the methods of determining the useful effect of our engines. It is hardly necessary to remark upon the superficial and crude nature of the results generally given concerning the performance of a steam engine, results indicating the amount of fuel burned per hour, the unit of work upon pistons and cranks.

We often see the consumption indicated with the minutest accuracy in figures containing two or three decimals; and this without the slightest mention of the kind of fuel employed, though it is well known that the heating powers of combustibles vary greatly, so that an engine can run more economically with 2 kil. of one sort of fuel than with 1.50 kil. of another. What value have such reports?

Suppose the kind of fuel accurately stated; still the figure of consumption per H. P. has no scientific value because it confounds in one estimate a set of distinct elements which should be separately examined, as the amount of steam and its use, the work of the generator and that of the engine.

This is clear. Take for example an engine that uses 10 kil. of steam per H. P. This is supplied by a boiler set under very bad conditions, vaporizing only 5 kilog. of water per kilog. of fuel. The consumption is 2 kil. hourly per H. P. Another engine may use 20 kilog. of steam, but if it is fed by a generator that very perfectly vaporizes 10 kilog. of water per kil. of fuel, the gross result of consumption per H. P. will also be 2 kilog. There is no apparent difference between the two.

The careful examination of this question is of great interest, for it leads to an important result: the conclusion that, if we give to the better of the two engines the better generator; or, if to the generator is attached an engine that utilizes the steam in the best

manner, then, instead of 2 kilog., we should have 1 kilog. of consumption, or 50 per cent. economy.

That steam engines have been gradually brought to their present perfection, is due to the minute and careful analysis of the physical phenomena which convert the heat of coal into a motor force. It is easy to indicate the necessity of the separate study of the elements of the steam engine, but not easy to represent this separation in practical experiments. But it is possible, in land engines, to take a satisfactory account of the interior action of the apparatus, both by observation of the weight of fuel burned and of water converted into steam, and by measuring the work on the shaft by the Prony brake and the work upon the piston by the indicator. But in the case of great marine engines, the weight of fuel and the work upon the pistons are the only elements easily measured. Results must be obtained by comparison or by approximation, somewhat coarse, it is true, but yet of great interest, and with much probability of correctness in them, because of the great number of facts we have at hand.

In marine engines, the expenditure of steam—and therefore the performance—is generally estimated by what is termed the weight of sensible steam in the cylinders; that is, the weight as shown by the indicator diagrams. As we have seen, this indication is often illusory. Though in engines in which the condensation in the cylinders is limited by suitable conditions of action, it may approach the real figure, so as to give results accurate enough in practice, still, in other cases, it gives results of no possible value.

This weight of sensible steam in the cylinder, which we shall call P′, differs from the weight P′ of water actually vaporized in the boiler, because it does not take into account the loss of steam by leakages, condensations in the tubes or at the entrance to the cylinder, by dead spaces, etc. But it also differs from the weight p of steam theoretically necessary for a given pressure and expansion; because it takes into account the various restrictive elements of the motor force, such as the reduction of pressure between the boiler and the cylinder, the phases of distribution, lead, compression, actual expansion, obstruction, etc. Hence, in general

$$P > P' > p.$$

Further on we shall find apparent exceptions, for which we should be prepared.

We shall first determine, for various pressures and expansions, the theoretic weight of the vapor p consumed hourly to produce the work of a H. P., on the piston.

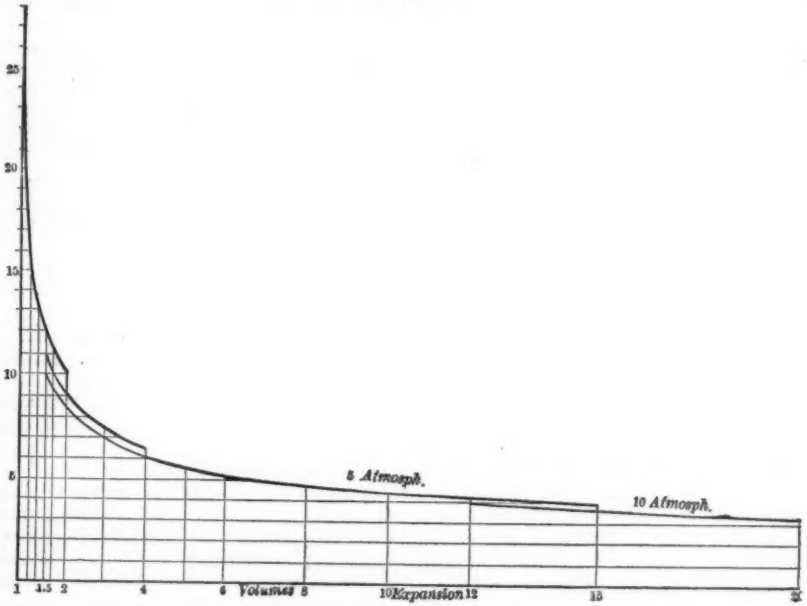
The following table gives the values of p for several kinds of marine engines. The figures are *theoretic*, being obtained from the formula for the work of steam. Only the resisting pressure in the condenser, estimated at 2 metres of water, is taken into account.

The figure illustrates the results graphically.

EXPANSION.	MODE OF ACTION.			
	Low pressure engines, 1½ atmosphere boiler pressure.	Mean pressure engines, 2¾ atmospheres boiler pressure.	High pressure engines, 5 atmospheres boiler pressure.	Very high pressure engines, 10 atmospheres boiler pressure.
Volumes.	kg.	kg.	kg.	kg.
1.2	14 50	.....	.....	....
1.33	13.33	12.10	.....	....
1.50	12.20	11 05	.....	....
2.	.....	9.16	8.31	....
2.50	.....	8.10	7 34	....
3	.....	7.42	6.75	....
4	.....	6.50	5.90	....
5	.....	.....	5 40	....
6	.....	.....	5.05	....
8	.....	.....	4.60	....
10	.....	.....	4 25	3.92
12	.....	.....	4.05	3.70
15	.....	.....	3 80	3.50
20	.....	.....	....	3.25

The weight P' of sensible steam in the cylinders shown by the indicator, should be more than the theoretic weight p, since the steam loses in various ways during its work. Of these losses, some are shown by the diagram, others are not sensible and introduce so many errors into the results that they are really not of practical use. They are almost exact enough for engines in which the condensation in the cylinders is a minimum. But they answer only when comparison is made of engines whose actions are

FIG. 5.



nearly identical. Useful results may be obtained respecting the distribution of the steam and the resistances in passages, pipes, etc.

The rate of the expansion normally employed ought to regulate the disposition of the parts of the engine; an engine constructed for a certain expansion will not work so well with a much greater expansion. The reasons have already been given; we add experimental confirmation as given in a table from "Engineering," in which is shown the weight of sensible steam in the cylinders of compound engines, each working with 3 deg. of expansion.

Number of engine.	1.		2.		3.	
Expansions	5 6	10	6.55	13.75	7.4	16 74
Absolute pressures	5.4 k.	5 k.	5.4 k.	5 k.	5.2 k.	4 7k.
Velocity of piston	1.77 m.	1.49 m.	2.175 m.	1 75 m.	1 98 m.	1 56 m.
Weight of sens. steam in cyl per hour and per h. p.	6.38 k.	6.43 k.	6.61 k.	6.43 k.	6.84 k.	7.29 k.

This table shows that the increase of expansion in the same engine increases instead of decreasing the consumption of steam. It is true that in the examples cited, action with full expansion corresponds to the least pressures and velocities of the pistons, and that there should result a diminution of useful effect of steam and an increase of losses by interior condensation. But the advantages due a greater expan-

sion would more than compensate if it should act under normal conditions, precisely what it does not do. With an engine set to expand 5 or 6 volumes, expansions of 10, 12, or 15 volumes can be had only by a corresponding reduced admission into the first cylinder, so that one falls upon some of the inconveniences of single engines, to say nothing of the losses of pressure due to the intermediate spaces and passages of double cylinders.

We call attention to the ratio between the weight of sensible steam and that of the theoretic in order to warn the reader of an error which has escaped the notice of many persons. We annex a table.

Designation of engines.	Absolute boiler pressure.	Expansions.	Theoretic weight of steam per h. p.	Weight of sensible steam, P′, per h. p.	Ratio. $\frac{p'}{p}$	Consumption of fuel per h. p.
	k.		k.	k.		k.
Woolf stationary engine	5.15	10	4.25	5.60	1.30	0.95
Aigle, imperial yacht	2.70	1.66	10	8.87	0.89	....
Abeille	2.12	1.54	11.30	10.50	0 90	2 25
Frigate, 250 h. p.	2 47	1.54	11	11 10	1.00	1.75
Steamer, 600 h. p.	2.10	2	9 50	10.79	1 14	1.78
Swift Steamer, 900 h. p.	1 98	1.66	10.70	12 00	1.12	1.64
Compound engines, 1.	5.40	5.60	5.20	6.38	1.22	....
Id. 2	5.40	6 t5	4.90	6.61	1.35	....
Id. 3	5.20	7.40	4.70	6.84	1.57	....
Hercules, tug	2.17	1.66	10.35	13.00	1.25	....

The first thing remarked in this table is that, while for most engines the sensible is greater than the theoretic weight, in other cases the ratio is one and less. Again, where this ratio is small, the consumption is increased, showing that the economy of steam is only apparent, there being no reason for supposing that the generation in the boiler is any less than in the other cases.

The conclusion is that we must not judge of the economy of an engine by the low rate of apparent expenditure of steam.

The explanation of this somewhat paradoxical result is simple, depending entirely upon what has been said above of the action of certain single engines without jackets. The vaporization during the period of expansion of the water condensed in the cylinders, produces a total work greater than that which corresponds to the apparent weight of water in the cylinder; although this work is often much less than that which is due to the amount of steam from the boiler. Besides, the steam in the dead spaces expands during the period of expansion. The error is due to the fact that the diagram indicates only the presence in the cylinder of the vapor in a gaseous condition during the period of admission; that is, a part only of the steam which has entered the cylinder, which leaves it at the end of the stroke. One cannot be too careful in avoiding the errors which result from a superficial examination. We insist upon this point because it seems to have escaped the notice of writers, the majority of whom say nothing about it.

Though the value of the weight P′ is not of importance, it is otherwise with the quantity P, which represents the amount of water vaporized in the boiler. Unfortunately the direct measure of this quantity is attended with certain difficulties, and is possible only in a few cases. Especially in marine engines, where results are not to be obtained by experiment, we are obliged to deduce the weight of the fuel by assuming that we know the weight of water vaporized per kilogramme of fuel (an element which can be determined for a given fuel and generator), or to calculate it approximately in terms of p or P′.

In the first case, *i e.*, when P is deduced from the weight of fuel burned, it is necessary to take into account the water taken up by the steam, which tends to increase apparently the vaporization, and also to take into account the loss of heat by *extraction* when the boilers are fed with water containing salt. It is important to do this when comparison is made of engines condensing by injection with engines provided with surface condensers.

In land engines it is easier to measure directly the water introduced into the boiler, an element which should be determined as

accurately as possible in experiments. In the example cited, of a Woolf beam engine, the weight of water vaporized per H. P. was found to be 6.5 kilo.; hence we have the following values:

P	6.50 k.	1.53	1.00
P	5.60	1.30	0.85
p	4.25	1.00	0.653

At sea, where boilers of the same kind and action may be assumed to have almost identical vaporization, P may be estimated from the amount of coal burned. For example, we may assume a vaporization of 8 kil. of water per kil. of fuel, which is not too high an estimate for good coal, even with salt-water feed. The value of $\frac{P}{p}$ may then be deduced, and a sufficient number of data would determine the value of P in terms of p.

An examination of results from a very great number of engines, gives a mean ratio of 1.55—nearly the same amount as that obtained by direct measurement; so that we may safely assume the value of $\frac{P}{p}$ between 1.5 and 1.6. In some cases, it is true, this ratio is 1.3, and even 1.25; in others, it is 2. We must conclude that in the first case the vaporization is a little more than our assumed figure (8 kil.), and that, in the second case, there are special causes of the loss of steam. We do not give 1.5 or 1.6 as an exact coefficient; but we think it may be admitted as a mean value, and employed in *projets*.

A question occurs. The 50 or 60 per cent. which should be added to the theoretic weight of steam expended per hour to produce a H. P. of 75 kilogrammetres upon the piston, represents losses of all kinds, from boiler to condenser. Can these losses be reduced by suitable precaution and care in the construction of engines? The answer is, that it is to these reductions, and not to increase of expansion and tension, that we are to look for future improvements. It would be a great gain to reduce $\frac{P}{p}$ to 1.40 or 1.33.

We find that there is little to gain in the way of expansion; and possible increase of tension is very limited, on account of the difficulties in disposition of boilers, and those attendant upon too high a temperature. It does not seem possible, theoretically, to expend less than 3.50 kil. of steam; assume, rigorously, 3.25 kil., answering to a tension of 10 atm. and an expansion of 20 volumes. We suppose the most conditions perfectly favorable.

For the ratio $\frac{P}{p} = 1.50$, the weight of water to be converted into steam per H. P. is about 4.90 k. This, with a vaporization of 8.5 k. per kilogramme of fuel (with surface condensation), would lead to a consumption of 0.58 k. per H. P. per hour.

With the ratio $\frac{P}{p} = 1.33$, there would be the same result, with a theoretic weight of steam 3.70 kil., answering to an expansion of 12 volumes only to a pressure of 10 atmospheres; an expansion much easier to effect, and requiring dispositions much less complex than expansions of 20 volumes. Were it possible to combine the reduction of the ratio with the minimum expansion, the consumption would be reduced to 0.500 k.

So far, we have sought only for improvements in making use of the steam, without regard to the method of its generation. It is obvious that progress may be made in this direction, and that it may be considerable. For example, if the production of steam per kil. of fuel could be brought to from 8.5 k. to 10 k.—a result not hopeless—the expenditures would be reduced to 0.85; becoming 0.50 k., in the first case, and 0.43 in the second.

Such results will certainly not be obtained without great efforts; but we may reasonably hope to approximate them with means already at our disposal, while, in our opinion, it would be chimerical to attempt directly to reduce consumption by means of radical modifications in the generation and use of steam.

An objection is often urged, that it is indeed possible to make economic engines, but on condition of employing costly and cumbrous devices, too heavy and bulky.

A steam-engine consists of a generator to produce the motive vapor, and an engine to put it to use. The weight of an engine is in a certain measure controlled by its proper disposition, especially with regard to rapidity of action, while the weight of the generator necessarily depends only on the generation of steam and the pressure at which the steam is produced. The weight of the generator includes the weight of the boiler and the water it contains

Boilers may be referred to various elements; as to the unit of power, the unit of

grate surface, the unit of heating surface, etc.

For our purpose the unit of weight of fuel consumed is convenient; but care must be taken not to draw from the figures conclusions which they do not warrant. It is obvious that the weight of the boiler, per kilogramme of fuel, will be less in proportion to the amount of fuel burned every hour, and hence, that this weight will vary with the activity of combustion, and will not in any way give the measure of economical use of fuel and metal; hence the considerable differences in boilers of the same type. The true method of determining the efficiency of generators, with respect to weight, is to refer to the kilogramme of steam—if only one could get direct data of this element; but as this must generally be deduced from the weight of fuel, it is as well to make direct reference to it.

We prefer, in all cases, to refer to the weight of coal burned, rather than to the square metre of grate surface. This would be rigorously possible only in case the boilers burned the same quantity of coal; but as the consumption may vary within wide limits without a corresponding sensible change in the production of steam answering to a kilogramme of fuel, we may ask, what is the real value of such a mode of estimation?

With the above reservations, our method of measurement will permit us to take account of the possible results of a given kind of boiler.

The following table contains results corresponding to various kinds of boilers.

DESIGNATION.	Weight in kilogrammes of coal per hour.			KIND OF BOILER.
	Of empty boilers.	Water.	Of full boilers.	
	k.	k.	k.	
North, Crampton	15.2	5.8	21	Locomotive.
North, 4 cylinders	24.6	7.4	32	Id.
North, moyennes Creusot	33.5	9 5	43	Id.
Francoise 1er	28	20	48	Cylindric tubular. cast steel.
Machine compound	58	17	75	Cylindric tubular.
Steamer, 900 h. p.	49	26	75	Regulation.
Steamer, 800 h. p	31	22	53	Id.
Ulster	36	26.5	62.5	Tubular return flue.
Tasmanian	43	32	75	Id.
Sphynx	68	41	109	With galleries.
Eldorado	55	50	105	Id.
Roanoke	76	42	118	Martin.
Brooklyn	65	51	116	Id.
Donawerth	35	24	59	Lamb and Summers.
Colombo	75	55	120	Id.
Guayaquil	61	51	112	Spiral, Randolph and Elder.
Hirondelle	31	2	33	Belleville.

Because of the tendency toward high pressures, it is probable that there will be a return to that type of locomotive boilers, which easily support pressures of 10 atmospheres, and which being fed with fresh water will give rise to no difficulty; always, with the condition of their having sufficient draft. It is clear that one of the first steps in improvement of marine boilers must be the adoption of means for producing an energetic draft. These boilers weigh at most, 43 kil. per kil. of fuel consumed; in some cases, 20 to 30 kil.; 40 kil. may be taken as an average. Another solution may consist in the use of the Belleville boilers, which, on the Hirondelle, gave 33 kil. But this figure should probably be increased on account of the fact that the coal was not well utilized. At any rate, we must admit the existence of boilers which do not weigh, water included, more than 40 kil. per kil. of fuel consumed hourly. A boiler of this kind feeding an engine expending only 0.5 k. per H. P., would weigh only 20 kil., water included, for the same unit.

Observing that the lighter boilers in combination with the most economic engines weigh 60 kil. per H. P., and the total, 80 to 100 kil., and more, we see that an economy of weight of 40 kil. at least, and possibly from 60 to 80 per H. P. is realized.

This weight, referred to an engine which, for a velocity of 60 revolutions per minute, weighs 80 to 100 kil. per H. P., represents

a bonus of 50 per cent., which would allow an increase of the weight of the cylinders and their accessories; for it must not be forgotten that the excess of weight due to the increase of expansion affects only those parts on which the steam acts, and not the parts that transmit motion; while the parts that relate to condensation follow the reduction of the weight of the boilers. It is easy to verify this assertion rigorously. The development of the power in every steam-engine corresponds to a certain volume described by the pistons in a unit of time. This volume varies with the tension of the steam, the degree of expansion, and the efficiency of action of the engine.

The volume for a unit of power is found by multiplying the volume of the cylinders by twice the number of revolutions in a unit of time, and dividing this product by the indicated power. It can also be directly obtained without knowledge of the dimensions of the engine, by dividing the value of a unit of power by the mean effective pressure on the pistons, as shown by the indicator.

The volume, V, per H. P. is

$$\frac{\pi r^2 2 c n}{P};$$

P being the power; but as $P = \pi r^2 2 c n p$, p being the mean effective pressure of the steam, we have $V = \frac{1}{p}$.

It is more convenient to refer this to the minute. We have calculated for a great number of engines of all kinds.

In certain engines, in which builders have thought that they obtained lightness, they have sacrificed the performance; the volume per H. P. and per minute falling to 0.250 cm., and even to 0.200 cm. In most engines of ordinary action with tension at 2.5 k. and 2.75 k., this volume is 0.300 m. c. to 350 m. c.

In the compound engines, mentioned by Bramwell, acting with full expansion, but at higher tensions, we find 0.385 cm. and 0.658 cm., as extreme values; the mean being 0.450. In engines with less expansion the values range from 0.300 to 0.400.

We infer that for the same number of revolutions, the volume of the cylinders will be increased only in the ratio of 1 to 1.5, an increase of volume corresponding to an increase in weight from 1.25 to 1.30. But suppose the weight rises to 1.50 or 2, so as to take into account the presence of jackets and the increase in section of slides and ports. In stamping engines, nowadays much used, the average weight of the cylinders with pistons and slides is 30 per cent. of the whole engine; it follows that, in this case, for a weight of 100 kil. per H. P., we should have 130 kil., or an increase of 30 kil.

We have seen that the minimum economy for boiler is 40 kil. We infer that a reduction of boiler-weight due to better use of steam, will permit the increase in weight of cylinders and pistons required by increase of expansion.

THE ELEMENTS OF COST OF RAILROAD FREIGHT TRAFFIC.*

By O. CHANUTE, C. E.

The subject of determining the cost of railroad transportation is seemingly a very simple one. So simple that to one unacquainted with the subject, it doubtless appears capable of easy solution, after a brief investigation. And, indeed, when, at the close of the year, the report of a railway company is published, it is comparatively an easy matter to reduce its whole business to an average number of passengers and of tons of freight transported one mile, and to ascertain approximately the average charges and cost of each. We thus obtain, however, only averages and nothing more. It is when we attempt to look further into the subject, and inquire why this average cost varies upon different lines, and what are its various elements, or to ascertain what profit has been made upon a particular class of the traffic, and what portion has been done at a loss, that we find very considerable intricacy and complication.

It is found, not only that this cost varies greatly upon different roads, in consequence, as we shall see, of local peculiarities, but that even upon the same road, it varies materially from year to year and from month to month. A comparison, by the reader, of the monthly earnings and expenses of al-

* Transactions of American Society of Civil Engineers, prepared from notes used in the discussion of "The Elements of Cost of Railroad Traffic."

most any railroad, will exhibit the fact that their ratio is far from being uniform; that the cost of carrying a passenger or a ton a mile varies 30 and 40 per cent. between the different months, and that in some cases the whole of the traffic is actually worked at a loss during some portion of the winter months.

The ultimate purpose of the investigation, which led to the remarks from which these notes are taken, being to ascertain the cost of particular operations upon a single road, it was thought necessary first to ascertain whether the division of the various elements of cost had been assumed correctly, by comparison of several roads. The present object, however, being only to indicate what those elements are, and the manner in which they burden the traffic differently upon the several roads, the present paper will be confined to a discussion of those elements, to the pointing out of their numerous combinations, and to such general deductions as seem to spring therefrom.

And first it may be stated that the problem of separating the various elements of the cost of railroad traffic, is probably incapable of exact solution with our present knowledge. The various expenses of which they are composed are combined with each other in so many different operations, that it is very difficult to separate them, so as to ascertain the cost of any particular class of traffic with mathematical certainty. We may approximate to it, however, and thereby gain clearer ideas on a subject which we will find to be very intricate.

Even the preliminary step of separating the cost of passenger from that of freight traffic is found difficult and unsatisfactory. Not only are many services incidental to each performed by the same agents, and there is great uncertainty as to what proportion of the maintenance of the way and works should be charged to each, but there is great diversity in the mode of keeping the accounts on different roads, and the basis furnished by the companies themselves is found upon examination to be arbitrary and somewhat unreliable. For the present, however, the figures have been taken as returned, merely making such corrections as seemed obvious, and the apportionment will be made from this.

Indeed, so complicated does the subject become, upon even a slight examination, that railway managers are very loath to commit themselves to positive statements as to the cost of particular portions of their traffic, and much of the reticence which has recently been sharply criticised during the discussion which has been going on in the public prints on this subject, is no doubt due more to an unwillingness to put themselves on record concerning many points which are by no means clear even to themselves, rather than to any disinclination to enlighten the public.

Table I., prepared from the Reports of the Engineer of the State of New York, shows the variations of charges made, and the cost per ton per mile, upon seven of the railroads of this State, during the last ten years, as well as the varying ratio of the cost of operating to the total expenses. It exhibits not only that the cost has been four times as great on some roads as upon others, but also that it has materially varied from time to time upon the same road; so that, for instance, had the average rates of charges prevailing in 1863 been maintained until 1865, when the war had raised the cost of labor and materials, six out of the seven roads would have been operated at a loss.

In order to account, if possible, for the cause of the difference of the cost per ton per mile, upon these several roads, an analysis has been made of their expenses for the year ending on the 30th of September, 1872. We thus obtain, it is true, only averages resulting from many different operations for each road, but we may be able to draw some inferences from them. Table II. shows the cost of transporting freight for 1872 on those roads, under seven general elements of cost, reduced to four common standards (such as could be obtained from the reports), under the heads of cost per ton per mile, cost per mile operated reduced to equivalent single track, cost per mile run by freight trains, and cost per ton transported. If, upon examination, there appears to be any uniformity in any one element of cost, under any one head of the division, it would be considered probable that this element operated alike on the different roads, and that the particular head under which the coincidence occurred was probably the best common measure of comparison. It will be found, however, that the resulting burden imposed by each upon the traffic, differs widely upon the different roads.

The division of the elements of cost, adopted in the classification, is as follows:

1. That which is here termed "Roadway charges," and which consists of the repairs and renewals of the earth-works, masonry, ballast and wooden portions of the roadway —such as cross ties, bridges, buildings, fences, etc. The repairs of earthworks, masonry, ballast and cross-ties, have been obtained by distributing under this head one-third of the amounts charged to "Repairs of road-bed, except cost of rails." Taxes are also included in this account, and it may fairly be considered as a fixed ratable charge, independent either of the volume or character of the traffic; representing in a great measure the wear and deterioration from the action of the elements, and proving more or less of a burden, per ton per mile, in proportion to the business.

2. The "General expenses" comprising the expenses of general management and incidental contingencies. To be strictly accurate, this account should also include the cost of soliciting for and obtaining business, but as this cannot readily be separated from the amounts reported for "Agents and clerks," the whole of the "Contingencies" account has been included as an offset. This varies somewhat in proportion to the volume of the trade obtained, as well as with the length of the road, but seems quite independent of the distance the traffic is to be carried. It may in most cases be considered as an arbitrary charge of so many cents per ton obtained.

3. "Station service," comprising the items termed "office expenses," "agents and clerks," "loading and unloading," and "watchmen and switchmen," in the official reports, and covering the cost of handling and billing the freight. This varies nearly in proportion to the tonnage handled, but is quite independent of the distance it may be carried over the road. It may be considered as a specific or arbitrary charge per ton, to be pro-rated over the number of miles the goods are conveyed.

4. "Track repairs," which includes the surfacing of the track, and the repairs and renewals of the rails, spikes, and joint fastenings. This varies in some measure, but not in direct ratio with the tonnage transported, and the speed at which it is carried. It is greatly affected by the character of equipment placed upon the road, as well as by the permanence of its construction, and its peculiarities of climate and soil. In the absence of more accurate information on this subject, its best measure is probably the miles run by trains.

5. "Car service," embracing the lubrication, repairs and renewals of freight cars. This varies most nearly with the mileage made by the cars, but the time required to make a trip, unload the car, and return it to the general service, becomes an important component, and seriously increases the cost of local traffic.

6. "Train service" may be said almost to alone represent the transportation proper. It consists of the wages of the "conductors and train men," "enginemen and firemen," "fuel," lubrication, water service, and the repairs and renewals of the locomotives. This alone varies both with the tonnage and the distance it is carried, and alone can correctly be compared for different roads by reduction to tons transported one mile. Its cost upon each is affected by the character of the gradients and curves, which limit the maximum train which can be taken over the line, the proportion of empty cars which must be hauled in consequence of the preponderance of tonnage in one direction, the cost of wages and fuel, and in the case of new roads, by the impossibility of securing full loads at all times for the trains which it is desirable to run regularly.

7. The "Insurance," which mainly consists of the loss and damage accounts, and which is dependent upon the value or perishable quality of the articles carried.

Having thus distributed the expenses according to these seven different elements, and constructed the comparative tables, we are enabled to take up each division in detail, and by comparing the resulting charge per ton per mile as deduced from specific expenditures, whether it be referred to the standard of cost per mile operated, or per mile run by freight trains, or per ton transported, to inquire in what manner, and to what extent, each element forms a charge upon the general traffic, and helps to swell the cost of the whole. This analysis can only be followed by a close and frequent inspection of the table, and although, no doubt, irksome to the general reader, is yet necessary to an understanding of the very complex relations which the expenses bear to each other.

An examination of the table thus constructed at once discloses differences in cost, which no possible theory as to relative economy or efficiency of management can

account for It is seen not only that like operating expenditures upon different roads, whether referred to cost per lineal mile or per mile run by freight trains, impose very unlike burdens upon their aggregate traffic per ton per mile, but also that the character of that traffic makes a very great difference in the cost of transacting it.

Thus, the Rome, Watertown & Ogdensburgh R. R., which has spent but $2,670.70 per mile operated, upon its freight business, shows a cost of 2.641 cents per ton per mile, while the Erie Railway, which has expended $8,212.58 per mile, or over three times as much, shows but a cost of 1.037 cents per ton per mile, or less than one-half as much. The Rensselaer and Saratoga R. R., which has run its trains for $1.42 per mile, yet finds the cost 2.306 cents per ton per mile, while the New York Central R. R., which has run its trains for $1.35 per mile, finds the cost but 1.043 cents per ton per mile.

These differences illustrate the influence on cost, of the total volume of business done. It is seen at once that some elements of cost are in the nature of fixed charges, and neither materially increase nor diminish, whether a large or a small business be done. That others again are specific or arbitrary charges, which are nearly constant, whether the traffic is to be conveyed a long or a short distance; and again, others increase with the business, but not in direct ratio to it; while of those which increase in strict proportion per ton per mile, the cost is probably not over one-third of the whole. One effect of this is to burden those roads which do a small business with a much higher cost than those which have developed a large traffic. There are certain expenses which must be incurred to keep the road running, and they prove less or more onerous, as the tonnage is large or small.

More important still as affecting the cost, is the character of the traffic. The road making the best showing in the table is the Syracuse, Binghamton & New York. The cost for 1872 was but 0.704 cents per ton per mile, and by reference to Table I., it will be seen that it transported freight for two years, at a cost of 0.55 per ton per mile. Yet this road has expended this year but $3,273.74 per mile of road, while the New York & Harlem R. R., which has expended but $4,531.88 per mile, exhibits a cost five times as great, or 3.635 cents per ton per mile. The New York Central, on the other hand, has expended $8,127.72 per mile operated, and its cost is 1.043 cents per ton per mile. So that we see that it is not alone the doing of a large business which cheapens the cost, by distributing the fixed charges over a greater number of tons, but also the character of that business which may require more or less looking after or incidental expense.

Comparing more in detail the Syracuse, Binghamton & New York R. R., and the New York & Harlem R. R, which exhibit the two extremes in cost per ton per mile, we note that certain of their expenses per mile operated are substantially the same. The roadway charges, the track repairs, and the insurance, practically agree. They aggregate $1,731.74 per mile, in the case of the former road, and $1,662.15 per mile in the case of the latter; yet they impose exceedingly unlike burdens per ton per mile. It is in the other elements that the great saving occurs on the S., B. & N. Y. R. R. The general expenses are only one-quarter as much per mile operated, and less than one-fifteenth as much per ton per mile as on the Harlem R. R. The station service is less than one-half as much per mile, and imposes a burden only one-tenth as great. The car service and train service are only about one-half as much per mile, and become a charge of only about one-sixth as much per ton per mile, so that those expenditures which are specifically the same on these two roads, not only differ greatly in the result per ton per mile, but those expenses which are variable are much greater in the one case than in the other. The explanation is, not only that the one has a larger, and the other a smaller relative traffic, but that the former road does a through, and the latter a local business; and that the first mainly transports coal, and the second merchandise. It will be well, therefore, to examine each element of the cost separately, and to inquire how and to what extent it burdens the traffic.

First, as to the "roadway charges," we notice a remarkable uniformity per mile of road operated, in the first five of the seven roads in the table. They have each expended about $800 a lineal mile, in replacing perishable material, and maintaining their works, and yet this cost has charged their traffic from one-tenth to six-tenths of a cent per ton per mile in proportion to the

greater or less volume of business done. On the two last roads, which have expended less than the others (perhaps because it was not necessary that they should fully make the wear good for that year), the burden per ton per mile is, nevertheless, about three times as great as upon the road which has expended the most. Although part of the wear of wooden structures is due to the action of the trains, yet the greater part of it is caused by exposure to the weather. As this proceeds slowly, it is not necessary to renew an equal portion every year, and the amount expended will vary on each road in different years; but it will be noticed from Table I., that the yearly cost per ton per mile varies most widely upon the roads with the lightest business, probably in consequence of periodical renewals.

It may here be stated, that since making up Table II., the writer has had reason to believe that the proportion adopted of one-third of "repairs of road-bed" for the roadway charges, is somewhat in excess of the truth, and that a sum of about $600 or $700 a year a mile would probably cover the general cost of this element; but whether $600 or $800 per mile of road, the amount is a fixed charge, in no way affected by the volume of business, but burdening it more or less, according as it is large or small, and therefore very onerous to new roads with light traffic. These may perhaps evade the charge for a time, while everything is new, but the wear and deterioration is constantly going on, and sure some day to call for fresh expenditures, either from current earnings or from capital.

The burden imposed by "general expenses" is partly fixed and partly arbitrary. That is, there are some expenses which must necessarily be incurred in managing the line, and some which increase with the business, but not in proportion to it. As we should expect, therefore, the table exhibits great variations per ton per mile, while there is some correspondence in the columns in which it is given per mile operated and per ton transported. It is seen also to be affected by the character of the traffic, in the case of the Syracuse, Binghamton & New York R. R., whose business evidently requires very little soliciting or managing expense. Although its percentage to the other operating expenses is small, it may form, in the case of the long thin lines recently built in the West, an important element of the cost of the light traffic which they may expect for some time.

The "station service" imposes a charge which is much the same, whether the article goes a short or a long distance over the road. For four out of the seven roads, it is seen to amount to about 32 cents per ton transported, irrespective of distance; and a table will hereafter be given to illustrate how this charge alone may cause the cost to vary from 4 cents a ton a mile, to about half a cent a ton a mile. In fact, it is clear that the cost is the same for loading and unloading, checking and billing the freight, whether it is transported over the road 10 miles or 1,000.

We notice, however, some anomalies in the table. Thus station service on the Syracuse, Binghamton & New York R. R., is but 4 cents a ton transported; while on the New York & Harlem R. R. it is 35 cents a ton. This is explained by the fact, that while the cost per ton per mile, and per ton transported, is made up from the total number of tons carried, yet a part, in some cases a very considerable part, is received or delivered loaded on the cars, either in the interchange of business with other roads, or as being of those classes of goods which are loaded and unloaded by their owners. Turning, therefore, to the report of the S. B. & N. Y. R. R., we see that it carried 533,355 tons, of which 28,126 tons were reported as "of the products of the forest," presumably lumber; and 442,764 tons of "other articles," presumably mostly coal. This leaves but 62,465 tons to be handled, while the amount charged to "loading and unloading," amounts to $14,362.19, or 23.4 cents per ton of miscellaneous freight. On the Harlem R. R., on the other hand, there are but 170,779 tons reported as of "products of the forest" and "other articles," out of 377,537 tons transported, so that it is presumed there were 206,758 tons to be handled, at a cost of $41,817.55 for "loading and unloading," or 20.2 cents per ton. A similar calculation for the Erie Railway gives a cost of 25.8 cents per ton handled; so that the road which actually did its work the cheapest, finds this expense the greater burden, in consequence of the peculiarities of its traffic.

We come here upon an important cause of difference of cost of transportation between different lines. It is found not only

TABLE I.

Average Freight Charges and Cost per Ton per Mile on Railways in New York for Ten Years, as stated in State Engineer's Report.

YEAR.	NEW YORK CENTRAL.			ERIE.			LAKE SHORE AND MICHIGAN SOUTHERN.			SYRACUSE, BINGHAMTON AND NEW YORK.			NEW YORK AND HARLEM.			RENSSELAER AND SARATOGA.			ROME, WATERTOWN AND OGDENSBURG.		
	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.
	cents.	cents.	per cent	c'ts.	c'ts.	p. cent.	cents.	cents.	per cent.	cents.	cents.	per cent	cents.	cents	per cent	cents.	cents	per cent.	cents.	cents.	per cent.
1863.....	2.38	1 55	62.79	2 09	0.9	61.51	2.78	1.40	62 43	1 87	0,55	42 89	3 38	3.27	60.72	5 25	3,52	65 00	2 92	2 14	52.37
1864.....	2.72	2.00	71.91	2.33	1.45	66.27	3.29	2.10	60.45	1 29	0 55	41.55	5 55	4.90	75.78	6 85	3,95	49.59	3.28	2,67	55,32
1865.....	3,31	2 52	77.87	2.76	1.99	70.69	3.29	3,13	69.67	1.49	1 57	89.88	6 37	5 68	74.69	6.89	5 55	64 60	4 13	4,16	69,17
1866.....	2.92	2,07	75.49	2.43	1.65	72.58	3.45	2 71	67 30	1.48	0,92	65.85	5 88	4,10	59 70	7,28	5.49	70 81	3 68	3.43	65,83
1867.....	2.53	1 89	76.20	2 04	1 47	72 18	3,41	2.87	77 88	1,59	0 88	56,02	7.23	4,87	56,60	6,90	5.27	72,80	3,74	2.99	55 72
1868.....	2.59	1.64	64 24	1.92	1.35	77.51	3.46	2,63	78 07	1.53	0.89	62.16	7.62	5.78	64,31	....	....	.....	3,58	3.24	74 82
1869.....	2.21	1,30	58.09	1,60	1 17	79.29	2,83	1,88	68,73	1.92	1 50	74 47	7 32	4 88	65 44	2.81	2 06	67,67	3 70	2,84	62,35
1870.....	1,86	1 15	63,36	1,38	0 98	74,62	1.59	1,04	62.93	1.42	0.76	58,34	6 57	4,45	62 21	3,95	2,65	59,63	3.75	2 92	64.12
1871.....	1.65	1 01	61.80	1.43	1,01	71.06	1.46	0 97	66.70	1.61	1.24	75.83	6.91	4 92	60.64	3 74	2,98	72.02	3 82	3 19	68,19
1872.....	1.59	1,04	64,29	1.53	1.04	68,55	1.34	0.95	69.99	1.42	0.71	54,68	6,14	4.34	60 19	3.27	2.31	65.45	2 93	2.64	75.49

TABLE II.

Analysis of the Cost of Transporting Freight on various Railroads for the Year ending September 30th, 1872.

	New York Central.	Erie.	Lake Shore and Michigan Southern.	Syracuse, Binghamton and New York.	New York and Harlem.	Rensselaer and Saratoga.	Rome, Watertown and Ogdensburg.
Total freight earnings.....	$17,258,768 20	$14,737,251 50	$12,030,409 00	$556,091 03	$1,560,376 80	$1,013,853 09	$702,769 67
Total freight expenses.....	10,648 937 14	9,859,207 80	8,397,736 73	265,172 64	764,844 10*	679,228 07	592,895 56
Total miles operated.....	1,310.2	1,200.5	1.198.	81.	168.77	181.	222.
Average through tons‡.....	779,201	791,927	740,278	464,689	125,405	162,717	101,134
Average distance carried	232 34	170.86	209.10	70.57	55.73	52.88	66.73

COST PER TON PER MILE.

Roadway	cts. 0.107	cts. 099	cts. 0.113	cts. 0 172	cts. 0.614	cts. 0.334	cts. 0.408
General expense	0.023	0.039	0 028	0.008	0.126	0.109	0 125
Station service	0 136	0 187	0 158	0 062	0.624	0 320	0 865
Track repairs	0 231	0.191	0.204	0 190	0.687	0 635	0 576
Car service	0 137	0.145	0 130	0.058	0.371	0.158	0 364
Train service	0 397	0 353	0.303	0.203	1.180	0.735	0.768
Insurance	0.012	0.023	0 011	0.011	0.033	0 015	0.035
Totals	1.043	1.037	0. 47	0 704	3 635†	2.306	2.641
Total ton miles	1,020,908,885	950,708,902	886,853,169	37,639,618	21,039,166	29,451,790	22,451,836

COST PER MILE OPERATED.

Roadway	$831 20	$786 65	$835 93	$802 21	$765 23	$544 93	$412 58
General expense	182 08	30' 43	206 21	39 40	157 42	176 64	126 33
Station service	1,060 38	1,477 73	1,170 53	286 42	778 57	520 17	369 12
Track repairs	1,802 15	1,516 67	1,508 54	881 79	856 01	1,034 22	582 35
Car service	1,062 97	1,143 51	964 94	271 10	462 87	256 50	367 77
Train service	3,093 00	2,798 19	2,241 76	943 07	1,470 87	1,196 29	777 29
Insurance	95 94	183 40	81 89	49 74	40 91	23 89	35 26
Totals	$8,127 72	$8,212 58	$7,009 80	$3,273 74	$4,531 88	$3,752 64	$2,670 70

COST PER MILE RUN BY FREIGHT TRAINS.

Roadway	$0 13.77	$0 10 50	$0 14.83	$0 21.57	$0 32 45	$0 20.67	$0 26.73
General expense	0 03.01	0 04 08	0 03.66	0 01.06	0 06.68	0 06 70	0 08.18
Station service	0 17.56	0 19.71	0 20.77	0 07.70	0 33 02	0 19.73	0 23.91
Track repairs	0 29.85	0 20.22	0 26 76	0 23.72	0 36 30	0 39.23	0 37.73
Car service	0 17.60	0 15.25	1 17.12	0 07 29	0 19.63	0 09.73	0 23.83
Train service	0 51.22	0 37.31	0 39.78	0 25 36	0 62.37	0 45.38	0 50.36
Insurance	0 01.59	0 02.44	0 01.45	0 01.34	0 01.74	0 00 91	0 02.29
Totals	$1 31 60	$1 09.51	$1 24.37	$0 88.04	$1 92 18	$1 42 35	$1 73 03
Total freight train miles	7,911,257	9,004,051	6,752,291	901,200	397.985	477,157	342,654

COST PER TON TRANSPORTED.

Roadway	$0 24.78	$0 16 97	$0 23.71	$0 12 18	$0 34.21	$0 17.70	$0 27.23
General expense	0 05.43	0 06 61	0 05 85	0 00.60	0 07 04	0 05 74	0 08 34
Station service	0 31.62	0 31.8*	0 33.20	0 04.35	0 34 80	0 16.94	0 24.86
Track repairs	0 53 74	0 32 72	0 42 79	0 13.39	0 38.27	0 33 60	0 38.42
Car service	0 31.69	0 24.67	0 27.37	0 04.12	0 20 69	0 08.34	0 24 27
Train service	0 92 23	0 60 37	0 63.59	0 14.32	0 65.75	0 38 87	0 51.29
Insurance	0 02 86	0 03.96	0 02.32	0 00.76	0 01.83	0 00.77	0 02.33
Total	$2 42.35	$1 77.18	$1 98.84	$0 49.72	$2 02 59§	$1 21.96	$1 76 24
Total tons carried	4,393 965	5,564,274	4,223,434	533,355	377,537	556,931	336,440

* Additional freight expenses on Harlem for city transportation by horses .....$148,919 23, making total ..... $913,763.
† Additional cost per ton per mile on Harlem for city transportation by horses. cents 0.708, making total .....cents 4 343.
‡ Ton miles divided by miles of road reduced to equivalent single track.
§ Additional cost per ton transported on Harlem, for city transportation by horses....$0 39.45, making total....$2 42.04.

that the cost of loading and unloading, checking and billing goods, is independent of the number of continuous miles which they are transported over the line, but also that this arbitrary charge varies greatly upon different roads, in consequence of the nature of their business, and the proportion of it which requires handling. This may go far to explain the general prosperity of the coal roads, which, while they have been enabled to obtain very nearly the same rates as other lines, have been put to far less expense in the handling of their tonnage and management of their business.

While, therefore, the character of the traffic on each road compels a certain expense for station service, the length to which it is to be hauled governs the resulting cost per ton per mile. To illustrate the manner in which this element alone varies the cost of the traffic, the following theoretical table has been constructed on the basis of the cost for 1872, on the New York Central, and the supposition that while the cost of station service remains the same per ton, all the other expenses vary in proportion to the train miles.

TABLE.

SHOWING *the effect of arbitrary charges for station expenses upon the average train of* 130 *tons. The station expenses being assumed at* 31.62 *cents per ton handled, and all the remaining expenses at* $1.1704 *per mile run by train:*

miles cost.		*cts per ton per mile.*
10	$\frac{130 \times 0.3162 + \$1.1704 \times 10}{130 \times 10} = 4.062$	
20	$\frac{130 \times 0.3162 + \$1.1704 \times 20}{130 \times 20} = 2.481$	
50	$\frac{130 \times 0.3162 + \$1.1704 \times 50}{130 \times 50} = 1.533$	
100	$\frac{130 \times 0.3162 + \$1.1704 \times 100}{130 \times 100} = 1.216$	
200	$\frac{130 \times 0.3162 + \$1.1704 \times 200}{130 \times 200} = 1.058$	
[232	$\frac{130 \times 0.3162 + \$1.1704 \times 232}{130 \times 232} = 1.037$	
500	$\frac{130 \times 0.3162 + \$1.1704 \times 500}{130 \times 500} = 0.932$	
1,000	$\frac{130 \times 0.3162 + \$1.1704 \times 1,000}{130 \times 1,000} = 0.932$	

The above, however, is for the average train of 130 tons, which is thus small in consequence of the short runs consequent upon local business. If beyond 200 miles, therefore, we assume that the trains consist of 24 loaded cars, or 240 tons, the cost becomes:

miles cost.		*cts per ton per mile.*
200	$\frac{240 \times 0.3162 + \$1.1704 \times 200}{240 \times 200} = 0.645$	
500	$\frac{240 \times 0.3162 + \$1.1704 \times 500}{240 \times 500} = 0.551$	
1,000	$\frac{240 \times 0.3162 + \$1.1704 \times 1,000}{240 \times 1,000} = 0.519$	

If, however, upon arrival at their destination, there is not enough return tonnage to load more than 10 of these cars, and the remaining 14 must be hauled back empty, the cost of the return tonnage is as follows:

miles cost.		*cts. per ton per mile.*
200	$\frac{100 \times 0.3162 + \$1.1704 \times 200}{100 \times 200} = 1.328$	
500	$\frac{100 \times 0.3162 + \$1.1704 \times 500}{100 \times 500} = 1.255$	
1,000	$\frac{100 \times 0.3162 + \$1.1704 \times 1.000}{100 \times 1,000} = 1.202$	

It has here been assumed, that all the expenses, except station service, vary in proportion to the miles run by freight trains. This is in excess of the truth. We have seen that "roadway charges" and "general expense" cannot so vary, being mainly controlled by other circumstances; and if we now turn to the column of track repairs in the table, we find that it varies in cost from 20 to 39 cents per mile run by trains, and a further inspection shows considerable variations in cost between the different roads, under all four of the standards adopted, and indicates that the cost does not vary in direct ratio to the business done. Thus, while the Syracuse, Binghamton & New York R. R. has expended $881.79 per mile operated for track repairs, the resulting charge is 0.19 of a cent a ton a mile; and the Rome, Watertown & Ogdensburgh, which has spent but $582.35 per mile operated, nevertheless finds the charge 0.57 of a cent a ton a mile. In general terms, the three roads of lightest traffic in the table, find the cost of track repairs per ton per mile a burden about three times as great as the other lines.

The wear upon the track is produced by three elements: 1st, the locomotive; 2d, the cars; and 3d, their contents. It is, moreover, affected by the speed, and the gradients and curves. It cannot, therefore, be expected to be in any constant relation with the contents of the cars, or the tonnage of the road, except so far as this dictates the character of the trains which must be run, the proportion of empty cars which

must be hauled to provide for the business, and the full or partial loads for the cars, or for the locomotives, as a through or a local traffic predominates.

It is believed by the writer that a very large part of the wear and destruction of iron rails is due to the action of the locomotives. The exigencies of the service having led to the modern practice of placing upon driving wheels weights which approximate closely to the crushing point of iron, the locomotive alone, probably, does more mischief to the rails than the rest of the train. If this be true, it would follow that roads with a heavy traffic cannot afford to lay any rails but steel in their tracks, while it is probable that many lines now laid with iron, whose business is yet to be built up, cannot afford to run the heavy locomotives which most of them are provided with, and that they would save large future renewals by exchanging them for lighter engines. It will be noticed that track repairs alone amount to about 20 per cent. of the cost of transporting freight, so that the importance of selecting the very best material for the track becomes at once apparent. It is chiefly from this, in connection with improved methods of car and train service, that future cheapening of transportation is to be expected.

The unsatisfactory result of the analysis of "track repairs," contained in the table, may result from the fact, that as renewals of rails are made at periodical intervals, some of the roads may have expended more or less than just enough to make good the annual wear. In order, therefore, to obtain results of value, the comparison should be extended over a series of years. For the present, however, we may consider the analysis as indicating that the charge imposed by track repairs is not in direct ratio, either with the miles operated or with the train miles, nor yet with the tons transported one mile. It will also vary over different parts of the same road in consequence of curves, grades, variety of soil or character of traffic, so that it is not probable that it has the value of a constant charge of cost per ton per mile, either upon different roads or even upon different parts of the same road.

A comparison of the cost of "car service," per mile run by freight trains, shows a range from 7 cents to 24 cents per mile run. This may partly be caused by the difference in gradients upon the road, or the character of their locomotives, thus limiting the maximum train which may be hauled. We see, however, that while the cost was 19.63 cents per train mile on the New York & Harlem R. R., and this imposed a charge of 0.37 of a cent a ton a mile on the traffic, on the New York Central, where it was 17.60 cents per train mile, it imposed a charge of but 0.14 of a cent per ton per mile. The table shows considerably lower cost on roads doing a through, than on those wholly confined to a local traffic. This evidences the value of the component of time in this item of the cost; a car frequently requiring as much time to go to a station 10 miles distant, to be unloaded, reloaded if possible, and returned, as to carry the same load 300 miles; or that, as stated in the Report of the Massachusetts Railroad Commissioners for 1872, "wheels earn money only while they are in motion."

The cost of car service is also dependent upon the proportion of empty cars which the service requires to be hauled. It has been shown, while treating of station service, that if a return load can be obtained for only 10 cars out of 24 (a not unusual proportion on most of the roads tabulated), the cost per ton per mile of their contents will be more than doubled. This again indicates the smaller cost of through, as compared with local business, it being far more easy to obtain a return load promptly from a terminal than from a local station. Indeed, it is probable that were a stream of through traffic, say of one million tons a year, thrown upon the Harlem road, the cost per ton per mile on that line, which is now 3.63 cents, would at once be reduced to about one-half that amount, so that it might cheapen its charges to all its patrons.

It is to be regretted that the reports to the State Engineer do not give the mileage made by freight cars, as this would furnish an excellent basis of comparison. It might, perhaps, be obtained by multiplying the train miles by the return giving the average weight of freight trains, were the latter correct; but they have been so evidently guessed at, as to possess no value.

When we take up the "train service"—the transportation proper, we expect to find at least some uniformity of cost between the different roads, some regular element of expense, and some solid ground on which to base a claim, that their charges shall be uniform. We refer to the table, and we find instead, that the cost varies per ton per

mile from 0.203 of a cent on the Syracuse, Binghamton & New York R. R., to 1.18 cents on the Harlem R. R.; or if we examine it by train miles, that it costs from 25 cents to 62 cents to run a train a mile. In order to account for this, the table on the next page has been made up of the cost, in detail, of running a freight train a mile upon the different roads for the year ending September 30th, 1872.

We see that while the repairs of engines have been pretty uniform, there are large differences in the cost of train hands, and especially in that of fuel. On the Central it is twice as great, and on the Rensselaer & Saratoga nearly three times as great, as upon the Erie, in consequence of their respective distances from the coal fields. The difference in cost of train men is to be attributed partly to variations in wages, but more particularly to the peculiarities of the road and traffic, which require a certain number of men to manage the trains, or to assist in handling the local freights at way stations. The same differences will be found to exist, though in a less degree perhaps, over parts of the same road, especially if seme portions are worked as branches and some as main line, and it would seem to follow that if strict regard to cost were had in adjusting the charges, they would have to be different for similar distances on the same road and its branches, in accordance with the character of the gradients, peculiarities of traffic, distance from fuel supply, etc., etc.

Cost of Freight Train Service per Mile.

	New York Central.	Erie.	Lake Shore & Michigan Southern.	Syracuse, Bingham-ton, & New York.	New York & Harlem.	Rensselaer & Saratoga.	Rome, Watert'wn & Ogdens-burg.
	$	$	$	$	$	$	$
Conductors and brakemen . .	0.0540	0.0931	0.0688	0.0251	0.2187*	0.0316	0.0780
Enginemen and firemen.....	0.0850	0 0889	0.0795	0 0318	0.1093	0 0832	0 1078
Fuel..	0 1822	0 0873	0.1487	0.1103	0.1524	0 2363	0.1983
Oil and waste...	0 0167	0.0131	0.0146	0 0130	0 0222	0 0166	0.0098
Repairs of engines.....	0.0946	0.0797	0.0832	0 0623	0 1128	0.0837	0.1000
Repairs of tools (half of total)...	0.0045	0 0045	....	0.0027	0.0039	....	0.0055
Water.	0.0091	0 0037	....	....	....	0.0024	0.0042
Incidentals.	0.0661	0.0028	0 0030	0 0084	0 0044	....	....
	0.5122	0 3731	0.3978	0.2536	0 6237	0 4538	0.5036

In every case, moreover, it will be noticed that the train service amounts to but about one-third of the total expense per ton per mile. Taken in connection with the car service, it is scarcely one-half of the whole, and the cost of these two elements varies from 33 cents to 82 cents per train mile, the roads of largest business varying from 53 cents to 69 cents; while the total cost of operating is from 88 cents to $1.92 per mile run by freight trains. Thus the transportation proper, which almost everyone has in mind when discussing railroad charges, costs but about one-half of the cost of the total service rendered to the public. The other expenses are in some degree fixed or arbitrary charges, or they do not vary with the distance to which the goods are conveyed, and burden the business more or less in proportion to its volume or character.

As to the "insurance," or losses incurred on goods in transit, it seems surprisingly small. It scarcely amounts to 2 per cent. of the whole expenses, or probably to about one-tenth of 1 per cent. upon the value of the articles carried. Perhaps a comparison for other years would make a less favorable showing than that selected as the basis of the table.

One important element has remained thus far entirely unnoticed, and nothing has been said about the interest upon the capital invested in the road and its equipment. This is as legitimate a charge upon the traffic as the cost of running the trains, and it must be covered by the profit charged upon the various shipments. In apportioning these profits, it becomes necessary, not only to consider the varying cost of each particular class of shipment, its volume, the expenses it occasions, the bulk or space it

* This item is so greatly in excess of every other, as clearly to indicate a discrepancy in the method of keeping the accounts.

occupies in the cars, and the risk incurred from its perishable properties, but also to use sound judgment as to its comparative value, and the amount of profit it will bear, so as to adjust the burden of transportation where it will least be felt.

It is well understood by railroad managers that the maximum of aggregate profit is by no means coincident with high charges. Every reduction of rates brings out for transportation more and more of the bulky and cheap commodities, and permits their shipment at a profit. This again cheapens the average cost of the whole by spreading the fixed charges, and those which do not increase with the traffic, over a greater number of tons; but as, in the meantime, the railroads must pay their operating expenses, and, if possible, interest on their cost, and as the business is not capable of indefinite extension, the adjustment of rates becomes a delicate operation, which requires careful experimenting in order to ascertain the rates which at any given time will yield a maximum of profit.

The universal tendency of rates in this country has hitherto steadily been downward. They sometimes have had to be raised on particular articles, but it has so invariably been found that those lines proved most profitable which developed the largest tonnage, by adjusting the rates so as to admit of the shipment of cheap articles, that it is deemed good policy to make the charges just as low as experiment proves to be prudent. The owners of new railroads, therefore, have generally been content to wait some years for full returns upon their investments, in order to promote the development of the country and of a large tonnage. But, as a compensation, they have collected more than the legal interest, whenever the growth of traffic has enabled them to obtain it.

It thus appears from this imperfect analysis of the table, which, it must be remembered, merely contains the average results of the very numerous and dissimilar transactions carried on upon each road during the year, that railroads do very much more than merely to transport the traffic which is intrusted to them. They furnish the road and rolling stock, and keep them in repair, and they load, unload, and insure the goods, in addition to carrying them. Some of these expenses have to be incurred whether a large or small business is done; many are independent of the distance which the article is transported, and others again are regulated by the character of the traffic. The cost varies with the season, with the character of the business, the value of the goods, and with the volume of tonnage which the year's crop, or prices in distant markets, brings forward for shipment, and it not unfrequently happens that a railroad knowingly transports a crop out of its tributary country at a loss, in order to furnish its patrons with the means of purchasing their annual supplies, and thus furnish profitable return tonnage for the line.

It will be seen that there is no term of comparison more fallacious, to apply to individual cases or particular shipments, than the average cost per ton per mile. This cost not only varies between the different roads, but it also varies greatly on the same road, either for different distances, or for the same distance over different parts of the line and branches. It varies with the class of goods, which requires more or less handling, and it varies even on the same goods, between the same stations, if empty cars are required to be hauled in one direction or the other. The transportation proper, including car service, is but about one-half of the whole expense, and even this varies with the cost of wages and of fuel. Railroad managers, therefore, in fixing rates to be charged, must estimate and weigh, as well as they can, the average cost of a great many different operations and contingencies, and make many attempts before they can ascertain the exact rates which will give the most profitable volume of trade, and the best returns upon the investment.

It would seem to follow, therefore, that the claim which is sometimes made, that charges for short distances shall be in proportion to those for long distances, is not founded on justice, and that tariffs cannot be made uniform, either upon different roads, or for like distances on the main stem and branches of the same road, under dissimilar circumstances of traffic. Neither can the rates be made permanent as to time, for although, doubtless, they should be changed far less frequently than they are, the cost is dependent upon so many varying elements, that a fair rate one year may be either insufficient or extortionate the next.

Even the claim, much better founded, that a higher rate shall not be charged for an intermediate than for a through distance, may be unjust in practice; the extra handling required, the furnishing of empty cars,

or the time lost by demurrage, may make the cost greater for the short than for the long distance. It should be stated, however, that it is believed to be good economy, as well as sound policy, not to make a higher charge from an intermediate than from a terminal station, and that the most ample notice should be given of proposed changes in the tariff, which should be uniform in its application. The cost in the majority of cases is no greater, and the ill-feeling which is sure to be engendered by the contrary practice, more than offsets any resulting profits.

It follows, also, that until experience and discussion shall enable us to understand the subject better, the making of a freight tariff is, and must be to a great extent, a tentative and experimental process, which cannot as yet be governed by any fixed mathematical rules. When, therefore, a freight tariff has been adopted upon a road, no matter upon what theory of the probable cost it has been based, it is straightway found necessary to modify it, either in part or by giving special rates, in order to conform with the particular circumstances of the case. As various communities prosper or retrograde, as certain articles increase or diminish in supply or in demand, changes have to be made in the rates in order to adjust them to the new relative importance or cost of the business.

To one unacquainted with the subject, these changes in the tariff seem, and some in fact are, arbitrary and unjust. It is perhaps from this very process of adjusting rates to cover a variable cost, which it must be admitted has not always been wisely or honestly done, that the great dissatisfaction at present existing with the railroads in the West originated a dissatisfaction which has led to legislation likely to be as tentative and experimental as the tariffs it seeks to control. In spite of this legislation, the result of this analysis of the cost upon the New York roads, renders it not improbable that the tendency will be in the future towards even greater diversity in charges than now exists upon roads in different parts of the West. Some of them are not now earning enough to meet their operating expenses, to say nothing of future renewals or returns upon the investment, and if they are ever to become profitable, they will be led to raise their freight rates if they can. This, however, does not wholly depend on the will of the managers. It is regulated by competition, and by the charges which the goods to be moved can afford to pay; so that the result of advancing the rates, upon many roads which have been built, would be to drive away or destroy the small amount of business which they now enjoy.

A country is enabled to sustain a railroad, pretty much in the ratio of the tonnage of its annual exportable products, and this determines, therefore, the distances apart at which it is most profitable to build them. This, in an agricultural section, varies with the crops which experiment shows it most profitable to raise. Thus in the cotton States, a single railway car carries off the product of 44 acres, assuming an average of half a bale per acre, and the roads are built about 60 miles apart. In Illinois, the proximity of the lakes makes it profitable to ship corn, which only requires the product of 7½ acres, at 50 bushels to the acre, to load a car, and the roads have been about 20 miles apart. In a region growing wheat, a car would carry off the annual product of 22 acres at 15 bushels to the acre, while in a pastoral country, it would require the product of 40 acres in cattle, or of 50 acres in hogs, to furnish a single car-load. As population proceeds westward, therefore, and engages in the raising of those products of greater concentrated value, in proportion to their bulk, which alone will bear the cost of transportation to a distant market, it must expect in the long run to submit to higher rates of rail transportation in the proportion of the diminished tonnage it will be enabled to furnish.

The same effect is produced by the building of more roads than are required to do the business of a portion of the country, under the mistaken belief that competition cheapens rates under all circumstances. The new roads, if in excess of the demand, while unprofitable themselves, will raise the cost upon the older lines, by diminishing their tonnage, and the consequent base upon which their fixed charges are to be apportioned. It is quite possible, therefore, that the recent extensive building of new roads in the West, while greatly adding to the convenience of the public, and cheapening transportation from the farm to the nearest railroad station, may yet result in an increase of freight charges, whenever the class of goods to be conveyed will bear any additional burden.

It is, perhaps, the indistinct recognition

of these facts which led to the system of granting subsidies, either in lands, municipal bonds or money, under which so many new roads have recently been constructed. This system has probably now passed the period of its usefulness, having induced the building of almost all roads really needed by the country, as well as a good many besides, which will not be profitable for many years, and which the owners are now very sorry to have built. Its true theory seems to be that the subsidy should form a fund, to defray the interest upon the capital invested in the road, during the years necessary for the development of its traffic, without interfering with the growth of the country, by imposing high rates of transportation. It is greatly to be regretted that it has been perverted in some cases, either by applying the subsidies towards the construction of the road, or by dividing them among the managers, instead of setting them apart as a reserve fund to tide over the first eight or ten years of unprofitable business.

It would lead us much too far here to discuss even the approximate cost of any particular class of shipments, or the fair rate which should be charged for it. This may roughly be done, by the general method here adopted while discussing the station service, of considering the cost of handling, billing and checking the freight, as an arbitrary charge per ton, irrespective of distance carried, varying with the character of the goods; and apportioning the other expenses in proportion to the miles run by freight trains, restoring, however, to each element its true value for the particular case in hand. This can only be done by taking up in great detail the accounts of a single road, upon which the particular shipment is to occur, and the result will chiefly be valuable for that road, and not for others; for even after the cost is ascertained, upon an assumed volume of business, it becomes a matter of judgment as to how much profit shall be charged in order to secure the maximum of revenue. All the previous calculations may thus be modified by the resulting and possibly different volume of traffic, consequent upon the introduction of the element of profit; while the subject more properly belongs to a discussion upon the relations of the railroads to the public.

The object of the remarks which led to the writing of the present paper, was to show how and why the cost and charges differed upon various roads. That purpose will be accomplished, if what has been said tends to promote such investigation and discussion by others, as to lead to a better understanding of the subject, and to the further investigation of the principles which govern the cost of railroad traffic.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—Proceedings of the Society, *March 18th*, 1874.—A stated meeting was held at 8 o'clock P. M.

A paper, by John G. Clarke, C. E., on the "Approximate Value of a Reduction of Ruling or Maximum Grades," was read and briefly discussed.

The subject, "Tests of Materials used in Construction and Testing Machines," considered at the stated meeting, held January 21st, was again taken up. O. Chanute, C. E., presented a report made by Russel H. Curtis, C. E., on "Tests of Eye-Bars for Iron Bridges on the Erie Railway," which was read, and a discussion followed.

April 1st, 1874.—A regular meeting was held at 1½ o'clock P. M.

The vote upon admission to membership was canvassed, and the following declared elected: Members, John M. Brown, C. E., of Auburn, N.Y.; Abraham B. Cox, Jr., C. E., of Rochester, N. Y.; Gen. William B. Franklin, of Hartford, Conn.; William F. Merrill, C. E., of Buffalo, N. Y.; Charles R. Schott, Jr., C. E., of New York: Joseph S. Smith, C. E., of Philadelphia, Pa.; R. Willard Ware, C. E., of Port Jervis, N. Y.; and Joseph Wood, C. E., of Washington, D. C.; and Juniors, Joseph B. Davis, C. E., of Ann Arbor, Mich.; David Reeves, C. E., of Philadelphia, Pa., and Samuel Whinery, C. E., of Butterville, Ind. The resignation, on March 12th, of H. L. Koons, C. E., Associate, of Los Angelos, Cal., was announced.

A paper, by Prof. Robert H. Thurston, on the "Strength, Ductility, and Resistance of Materials of Machine Construction;" a communication from Edward Turner, C. E., referring to the "Elements of Cost of Railroad Traffic," and one from Gorham P. Low, Jr., C. E., suggesting measures for making a comparative examination of the principal pumping engines in use, were read. The latter was referred for consideration and report to a committee consisting of Messrs. Gorham P. Low, Jr., John Bogart, W. Milnor Roberts, and William E. Worthen.

The expediency of a change in location of the rooms of the Society was referred to Messrs. John Bogart, Francis Collingwood, and G. Leverich, as a committee to obtain requisite information, and report to the Board of Direction, which was empowered to act in the matter.

OF THE BOARD OF DIRECTION.—*March 30th*, 1874.—A stated meeting was held at 2 o'clock P.M., and proposals for admission to the Society were considered.

A report from the committee appointed to prepare a detailed plan for the Sixth Annual Convention of the Society, to be held in New York, June 10th and 11th, was adopted; the Committee on Library was requested to present a scheme for the

division of the books, maps, and similar property of the Society, into works of reference, which shall not be removed from its rooms, and works which may be loaned to members; and the Secretary was instructed to send a circular to members of the Society and to managers of public works generally, asking the donation of new and old reports, odd pamphlets, and similar matter, which may furnish a basis for the history and comparison of engineering operations.

IRON AND STEEL NOTES.

STEEL PRIZE IN BERLIN.—It is known that steel, when quickly cooled after heating, assumes more or less hardness and brittleness; the color, texture, and density of the material being altered. As to the causes of difference between hardened and unhardened steel, there are merely conjectures on the subject. At a recent meeting of the Berlin Academy of Science, one of the secretaries, Dr. Du Bois Reymond, announced that a prize of 100 ducats (about £40) would be awarded in July, 1876, to any one who would best solve the problem, by experiment, whether the causes referred to were physical or chemical, or both. Accurate comparative analyses are required, especially of the relative quantities of carbon in the free and combined state, and also observations of the physical qualities of the materials. The memoir may be written in German, French, Latin, or English, and is to be sent to the Academy (with sealed note and motto) before the 1st March, 1876.

THE IRON PRODUCE OF THE WORLD.—The Official Report of the Vienna Exhibition gives the annual "output" of iron in the producing countries as follows: England (1871) 134,664,227 cwt.; Zollverein (German bund) (1871) 33,296,042; France (1871) 23,620,000; Belgium (1871) 11,406,480; Austrian Hungary (1871) 8,492,122; Russia (1871) 7,208,141; Sweden and Norway (1871) 6,138,347; Italy (1872) 1,474,180; Spain (1866) 1,474,180; Switzerland (1872) 150,000; total for Europe, 227,793,099. North America (1872) 46,900,000; South America, 1,000,000; Japan (1871) 187,000: other countries of Asia (approximated) 800,000; Africa, 500,000; Australia, 200,000; total for the world, 276,500,000 cwt. It appears from this statement that England produces more than one-half of the whole amount, North America, about one-fifth. France about one-twelfth, and Belgium one-twenty-fourth; these four constituting the great iron-producing countries of the globe.—*American Manufacturer.*

RAILWAY NOTES.

SPLICED CARRIAGES ON THE MEXICAN RAILWAY.—The Mexican Railway, which extends from the seaport of Vera Cruz to Puebla and Mexico, a distance of about 300 miles, has occupied several years in its construction. Political movements and changes of Government, and other disturbing influences have all done their share to retard the completion of this great enterprise. The entire system was completed and opened for public traffic in January, 1873. For some years previous to this latter date portions of this line, or from Vera Cruz to Paso del Macho, 47¼ miles, and from Puebla to Mexico, 115¾ miles, have been in operation.

As these pieces of line presented no very exceptional features in the way of curves and gradients, the passenger carriages of the ordinary English pattern were found to answer very well.

When pushing on with the construction of the remaining portion of the line, connecting the lower with the upper table-lands, it became necessary to consider some method of modifying the existing carriages to enable them to pass with safety and facility round the inevitable sharp curves which must be encountered in ascending the mountain range. The summit level of the railway on the upper table-land is some 8,400 ft. above the level of the sea, and the gradients and curves during the 60 miles before reaching that altitude are very heavy. There are more than 15 miles of line on one almost continuous gradient of 1 in 25, and also long and frequent lengths of 1 in 33, and 1 in 40.

It will be readily understood that if the characteristic features of the country necessitate such extremely steep gradients, so in like manner would curves of small radius become almost inevitable. In locating the line through the mountain range, advantage has been taken of the available spurs of the hillsides, and although heavy works have been constructed in the way of cuttings, embankments, bridges, and tunnels, it was found impossible, even with these, to obtain better curves than 325 ft., and 250 ft. radius, unless by incurring works of vast magnitude and expense. In view of these numerous curves of 325 ft. and 350 ft. radius, it was considered inexpedient to work the passenger traffic on this part of the line with carriages of the ordinary English pattern, having a rigid wheel base of 11 ft., 12 ft., or 14 ft. To have placed a four-wheeled American bogie truck at each end of so short a carriage, would have added greatly to the weight of the carriages, by employing eight wheels to carry the load, where four would be ample, and the tendency to lateral movement, inherent in the bogie system, would be much felt in a vehicle of so short a length.

It was at this time that the idea suggested itself to Mr. W. H. Mills, M. Inst. C. E., the general manager of the line, to splice the carriages together in pairs, and to make in this way one carriage about 45 or 48 ft. long, with an American four-wheel bogie truck at each end.

The carriages built by the Ashbury Carriage Company, England, offered special advantages for this splicing together. The main frames, which are of rolled wrought iron, have been spliced or fished together with strong wrought-iron joint plates 3 ft. 6 in. long, well riveted, thus making each of the main frames in one continuous piece or girder. To assist in stiffening these frames, three tension or truss rods 1¼ in. in diameter, have been placed and carefully adjusted under the carriages. The carriage bodies, which are of teak, have also been strongly bolted together at the sides and roof. A four-wheel centre-pin bogie truck built by Gilbert Bush and Co., of Troy, New York, has been placed at each end of the carriage. In addition to the Westinghouse air-brake, which is fitted up on all the carriages of the Mexican Railway, one brake placed on the top of

the carriage applies the brake shoes, which are of iron, to all the eight wheels at once.

The result of this splicing of two carriages together has been a perfect success, and all those that have been thus treated, are now by far the easiest and smoothest-running carriages on the line. They pass with ease around the sharp curves above alluded to, and for some weeks had to pass daily round two provisional curves of 150 ft. radius.

The first of these spliced carriages commenced to run in January, 1871, and has now been running daily nearly three years. No repairs have been required beyond painting, varnishing, and renewals of axle box brasses. Several other carriages have since been altered in the same way.

The carriages having first and second-class accommodation are 46 ft. 3 in. long, and carry 74 passengers. They have three first-class compartments, each holding eight persons, and five second-class compartments of ten each.

The carriages combining second and third class are 44 ft. 9 in. long, and carry 90 passengers. They have nine compartments, four for second-class and five for third-class, the compartments holding ten passengers.

These spliced carriages are in daily use on the through trains between Vera Cruz and Mexico, and are found equally efficient on the comparatively level and straight road on the upper plains, where the running speed is much greater than on the more difficult parts of the line. They are very easy both for the passengers and the permanent way, and are free from shaking when running at high speed, and do not grind when passing round sharp curves.

A Russian engineer named Sakhovsky has invented an apparatus—a kind of differential gauge—of very simple construction, which is said to have been found to work admirably at the Moscow terminus of the Nijni Railway, and on several other lines. The apparatus consists of a beam about 5 ft. long, provided at one end with an articulated lever, on the shorter arm of which is a stud that presses by means of a spring against the inner face of one of the rails, and at the other with a fixed stud; the beam is drawn along the rails by a man by means of shafts, or it may be attached to a truck. As the gauge proceeds along the line the deviations from the normal width between the rails is shown by the longer arm of the lever, which moves against a dial plate. The apparatus cost only eight roubles, and its superiority over the common gauge is striking, especially as regards the rapidity and continuity of the action. The Directors of the Nijni and other lines have adopted the invention, which we believe is patented. Such a gauge run along a line every morning might prevent many an accident.

Union Pacific Railway.—Last year this company began the boring of six artesian wells in the arid districts, in order to obtain supplies for locomotives, which had been in part supplied by water trains. The first well is at Separation, 724 miles from Omaha, and the last one is at Rock Spring, 832 miles. Another is in progress at Red Desert. The well at Rock Springs is 1,145 ft. deep; the bore is 6 in. in diameter. In all the wells it was necessary to tube a great part of the way. At Rock Springs the water rises from the depth of 1,145 ft. 26 ft. above the surface, and discharges 571 gallons per hour, and at the surface, 960 gallons. At Point of Rocks, 25 miles east, the well is 1,000 ft. deep. The water rises only to within 17 ft. of the surface, whence it is pumped, but the supply is abundant, and the quality of the water is the best of all the wells. The next well is at Bitter Creek, 21 miles east of Point of Rocks. It is 696 ft. deep. It yields, by pumping, 2,160 gallons an hour, and at the surface it flows 1,000 gallons an hour. Next, to the east, is the well at Washakie, 33 miles distant. It is 638 ft. deep, and at 15 ft. above the surface it flows 800 gallons an hour. At Creston, 14 miles east, the well is 326 ft. deep, and an ample supply of water is obtained. At Separation the well is 1,103 ft. deep, and water comes within 10 ft. of the surface, which by pumping yields 2,000 gallons an hour.

In some of the wells the water has 280 grains of salt in solution, and the incrustation is considerable; but altogether the wells have been a success, and, it is said, the cost of running water trains since the wells have displaced them would have paid for the wells.

ENGINEERING STRUCTURES.

Collapse of a Tunnel near Merthyr.—An accident has occurred in the tunnel between Merthyr Tydvil and Aberdare, on the Vale of Neath, Great Western Railway. This tunnel is about two miles in length. It passes through the mountain at an elevation of about 500 ft. from the bottom of the valley, and intersects many of the coal measures. Indeed, several years ago, the colliers working a neighboring colliery had got under the tunnel in the excavations, and were so close to the roadway that they could hear the trains rolling over it distinctly. The excavations of coal have proceeded, and it is supposed the cavities thus formed have seriously interfered with the bed of the tunnel. A passenger train from Swansea to Merthyr had a very narrow escape. It passed in safety; but a goods train which followed it half an hour afterwards became blocked, and it was found that the tunnel had collapsed, the locomotive half burying itself in the *débris*. Although there were continual falls, the engineers cleared for a train, and the passengers were in their places awaiting the signal, when suddenly alarming news was received that nearly a hundred yards more of the tunnel had fallen in, and traffic could not be restored for several days. Meantime the traffic had to be carried over the Taff Railway to Quaker's-yard Junction.

The Channel Passage.—A new suggestion, says the *Pall Mall Gazette*, for improving the Channel passage is offered by M. Roumieu. As the shallowness of the French and English shores and the constant shingle drift offer great hindrances to the formation upon the coast of harbors which will receive large steamers at any time of the tide, this engineer proposed to construct harbors two or more miles out to sea, approached by tunnels from each shore. Accommodation would thus be provided for vessels drawing such a depth of water as would insure steadiness of motion in any except stormy weather. The harbors (he

says) would present no engineering difficulties. They might be formed upon the same principle as the Plymouth breakwater, concrete blocks being placed by divers below the sea-level. Upon the superstructure a lighthouse would be raised which would also form a ventilating shaft to the tunnel. Access to the railway tunnel would be gained by sinking a large caisson to the necessary depth, and the excavation from it would help to form the outside slopes of the harbor. The tunnel on either side would not be of a length to require ventilation, except at the two ends, particularly as M. Roumieu proposes to dispense with engines, and the air would not therefore be deteriorated by smoke or steam. An inclination of the rails seaward would carry the train to the deep sea harbor; an endless rope, worked by a stationary engine, would draw the train back again. The passengers and their luggage would be brought to the water level by a powerful lift, and they would then embark on board large and swift steamers, which would perform the passage of, say, sixteen miles in about an hour, the transshipment being no more than is now necessary, and the liability to sickness being reduced to a minimum. Such is the compromise suggested by M. Roumieu between the proposal to tunnel all the way and not to tunnel at all.

THE TAY BRIDGE.—The report of Mr. T. Bouch, the engineer of the Tay Bridge undertaking, to the Directors of the North British Railway Company, states that the contractor for the bridge portion of the works had completed twenty spans, piers, and girders. The pier for another span was up to the full height, and ready for a set of girders. The piers of three spans were built up to within 26 ft. of their full height. Two piers were built up to 4 ft. above high-water line. Two piers were sunk to their full depth, concreted, and made ready for the columns above. Two piers were sunk about 17 ft. into the clay, and five caissons were placed in position on the bed of the river. Altogether there was a length of upwards of 3000 ft. of the bridge completed and in progress. He had been disappointed that more progress had not been made: but, besides the difficulty arising from the strata through which the caissons had to be sunk, the exceptionally severe gales in December and January last seriously interrupted the operations, and caused material damage to the staging and plant, but no damage was sustained by any part of the permanent works. As much of the work which had been done during the past six months was under water level, the progress really made was far in excess of what was apparent, and by the end of the next six months the bridge would present a very different and more satisfactory appearance.

ORDNANCE AND NAVAL.

THE NEW FIELD GUNS FOR THE GERMAN ARTILERY.—After the trials which took place in October last, in presence of the Emperor, the introduction of the light calibre of the future guns for the German artillery has been determined upon. The heavy calibre to be used, respecting which the choice lay between two models, has also at length been definitely adopted. The manufacture of the guns is in full progress at Krupp's establishment at Essen.

We ("Cologne Gazette") are enabled to give the following reliable particulars with regard to the new field guns. The light calibre, 7.85 centimetres, is similar to that of the former light 4-pounder field gun, or that of the 8-centimetre gun, the heavy calibre, 8.8 centimetres, being on the contrary, lighter than the old six-pounder or 9-centimetre gun, which had a calibre of 9.15 centimetres. The new light field piece will be introduced into the horse batteries, while all other batteries will be armed with the heavier gun. Both descriptions are so-called case or jacket barrels (Mantelrohre), *i. e.*, the cast steel barrel is, from the breech forward, as far as the trunnions, encased in a wrought-iron jacket, which is welded round it in a red-hot state, and, after cooling, tightly encloses it. The breech is the so called Broadwell cylindro-prismatic arrangement. Both kinds of barrels have 24 grooves, and a twist of 50 times the length of the calibre. The carriage is almost the same for both guns, so that only one kind of reserve carriage need be taken, and, in case of necessity, light and heavy batteries may mutually supply each other. The cheeks are made of a single piece of rolled cast-steel plate, bent in loop-form at the trail end for the formation of the pintle hole. The cheeks consequently do not run parallel, as formerly, but converge towards the end. The axle is likewise of cast steel, and only the wheels are still of wood. The latter are about 6 in. higher than formerly, and the height of firing of the new guns is raised about as much. The traditional blue color hitherto used for painting all the wooden parts of field artillery materials, is discarded; in future the wood is to retain its natural color, and will only have a coating of linseed oil to protect it against wet.

The limber will also have wheels considerably higher; the ammunition box will be made of sheet iron, and will not be opened, as formerly, from above, but will be divided into slides, four in a row, drawn out from behind. Each ammunition box will carry, besides two case shot, 20 shells or shrapnels, probably 10 of each. Besides these, two reserve case shot will be carried in a receptacle on the carriage cheeks.

The strengthening of barrel and carriage caused by raising the weight of the charge as compared with former guns, has involved an increase in the total weight of the guns. The weights of the different parts of light and heavy field guns will, in future, be as follows:

Weight of barrel 391 and 452 kilogrammes respectively, as against 290 and 433 respectively.
Carriage, empty, 473 and 525 kilogrammes respectively, as against 453 and 520 respectively.
Barrel and carriage ready for action 890 and 1010 kilogrammes respectively, as against 772 and 101 respectively.
Limber, empty, 472 and 480 kilogrammes respectively, as against 459 and 459 respectively.
Limber, ready for action, 830 and 870 kilogrammes respectively, as against 805 and 822 respectively.
The whole gun, ready for action, 1725 and 1890 kilogrammes respectively as against, 1579 and 1837 respectively.
Draught load per horse 290 and 322 kilogrammes respectively, as against 262 and 305 respectively.

It will be seen that the increase of weight is greatest for light calibres.

The new ammunition differs also essentially from the old. The shells are double-cased, *i. e.*, two separate cases are fitted in zig-zag into each other, inclosing one another. This clever contrivance multiplies the number of pieces in bursting, and consequently increases considerably the effect of the shot.

The double-case shell of the light gun makes, at a range of 1,500 metres, on an average 60, that of the heavy gun, 90 hits. The projectile is guided in the grooves, in place of the old lead casing, by two rings of plain copper wire, pressed into corresponding furrows of the iron core, and riveted together at the ends. This arrangement, however, has not yet been definitively adopted, more extensive trials having lately taken place with hard lead rings, fastened according to a peculiar method, at present the secret of the firm of Grüson, of Buckau. But at present the copper rings seem to have the preference, partly on account of cheapness, partly because preventing loss of velocity of the projectile by friction against the grooves. The shell of the light gun weighs 6.5 kilogrammes, that of the heavy gun 1 kilogramme more, the spherical case-shot 6.8 and 7.6 kilogrammes respectively, consequently not much more than the old projectiles. The powder charge, on the contrary, is 1.25 and 1.5 kilogrammes respectively, as against 0.5 and 0.6 kilogramme, more than double the old charge. This heavy charge insures very great initial velocity and grazing of the trajectory, and thereby considerably increases accuracy of firing, especially against vertical targets. At the trials held last October, at which the known distances of the old guns were in favor of them, at a distance of 1,500 metres, the effect of the shells of the old compared with those of the new guns was in the proportion of 1 : 2.5, that of the case-shot as 1 : 3. For shorter distances, on the contrary, the shell has been found to be relatively less effective, as in that case the great velocity inherent to the projectile had driven it deep into the ground before the percussion fuze acted and caused it to explode. The construction of quicker-acting fuzes is under consideration: on the other hand, a regulation forbidding the firing of shells in future at distances under 1,200 metres might be put in force. The model of the new case-shot, only to be used for repelling sudden attacks of cavalry, has not yet been definitively chosen. Tenders have been invited for the supply of iron cores for shells and case-shot.

The new powder, very coarse-grained, and similar to English pebble powder—each grain having the size of a hazel nut—is being manufactured in private as well as in State powder mills.

At present the works at Essen have in hand only the light guns, of which Prussia has ordered 458, and Bavaria 54 pieces—the total want for the horse artillery, inclusive of reserve batteries. It is intended to supply all horse batteries with the new gun before this year's target practice commences. Two batteries of the field artillery of the Guards have already been armed with it.

In future every battery will be furnished with a telescope and stand for observing the effects of the firing, and every officer will be provided with a level of the newest construction.

THE "CITY OF PEKING."—This latest addition to the Pacific Mail fleet of thirty-five steamers had not, up to the date of launching, been measured for register, but her gross burthen will fall very little short of six thousand (6,000) tons. Her extreme length of hull is 423 ft., by 47 ft. 3 in. breadth of beam, and she is 36 ft. deep between the top of the keel and the spar deck. She has four decks, and six water-tight compartments. She has accommodations for 150 cabin passengers, and 1,500 steerage passengers, and her coal bunkers will carry 1,500 tons. The bulkheads are fitted between double frames, so as to insure the greatest tightness and resistive power in the event of it ever becoming necessary to depend on them for safety. All the deck beams are placed on every alternate frame, with "knee" plates forged on them, and are riveted to the frames and stringers. Calculation has been made and jointings and sockets prepared for beams to support the engines and boilers in too many ways to admit of detailed description. The "shell plating" of the vessel varies in thickness. No plate is less than 12 ft. long, and each plate tapers to suit the ship's sheer. Every shell plate has been tested, before being put into the ship, to several times the strain, in both simple and compound relations, it can ever be called upon to bear in actual use. All shell plates are flush jointed on the vertical section, and lap jointed on the longitudinal section; they are all riveted according to the rules of the Bureau Veritas.

All the ship's skylights are arranged to combine the maximum of utility, strength and water-tightness. The rudder is of the best hammered scrap iron, and every means that intelligence has devised and experience confirmed as useful has been employed to render this important part of the vessel absolutely secure.

The City of Peking is furnished with the most approved steam steering apparatus, as well as two other hand wheel steering apparatuses, one forward and the other aft. The steam apparatus is furnished with a friction brake to hold or stop the rudder at any point, and with a pointer to indicate exactly at what degree the rudder is at any moment.

The engines of the City of Peking are correlative with the magnitude of the vessel. They represent 5,000 horse-power, and constitute, with one exception, the largest piece of mercantile marine machinery ever constructed. They consist of two pairs of compound engines. The stroke is 54 in. There are two low-pressure cylinders of 88 in. each, and two high-pressure of 51 in. each—thus giving an aggregate cylinder-diameter of 278 in. Either engine may be detached from the other, and in case of breakage of one of them at sea, the sound one may be worked while the other is in process of repair, and will propel the vessel at two-thirds of its regular speed. The pumps for circulating the water through the surface condensers are independent of the main engines, which is a decided improvement.

This colossal machinery is to be furnished with steam from ten cylindrical boilers 13 ft. in diameter by 10 ft. 6 in. long, the shell of each boiler being 13-16 of an in. thick, and double riveted. Each boiler has three cylindrical furnaces, with 204 tubes 3¼ in. outside diameter, by 7 ft. 6 in. long. The total grate surface in these ten boilers is 520

sq. ft., and the total heating surface is 17,000 sq. ft. This is the largest heating surface ever provided for the engine of any mercantile compound marine engines, and will evolve valuable economic results in permitting slow combustion of fuel while the machinery is at full working power, and thus insuring a development not very often attained—namely, the complete consumption of all the coal put into the furnaces.

The propeller is a Hirsch screw, 20 ft. 3 in. in diameter, with 4 blades, and a mean pitch of 30 ft. In case of leak the ship's pumps are capable of throwing 10,000 gallons (250 barrels) of water per minute. There are four donkey engines with separate boilers, which may be worked in connection with or detached from the main boilers. There are three freight hatchways on deck, each furnished with a steam winch for hoisting and lowering freight. The forward winch also works the anchor, and the sails are hoisted, set, and furled by means of these winches, thus reducing the labor of the crew to a minimum.

Nothing has been left undone to render the City of Peking, in every possible respect, an absolutely perfect vessel. She enters the water as the Pride of the American Navy, and, without detracting from the worth of any foreign vessel, has no equal now afloat available for commercial purposes. She is one-fourth larger than the Celtic, the largest White Star ship. Three years ago the almost universal belief was that no such vessel could be built except on the Clyde

BOOK NOTICES.

THE MOON; CONSIDERED AS A PLANET, A WORLD, AND A SATELLITE. By JAMES NASMYTH, C. E., and JAMES CARPENTER, F. R. A. S. London: John Murray. For sale by Van Nostrand. Price, $15.

One is led to wonder upon first taking in hand this elegant quarto how enough profitable reading can be gathered together to fill so large a book, and still treat only of the moon. The preface answers all rational inquiries as to the plan of the work, and the abundance of illustrations of rare quality create at once a new interest in the subject. We quote from the preface:

"The reason for this book's appearance may be set forth in a few words. A long course of reflective scrutiny of the lunar surface with the aid of telescopes of considerable power, and a consequent familiarity with the wonderful details there presented, convinced us that there was yet something to be said about the moon, that existing works on astronomy did not contain. Much valuable labor has been bestowed upon the topography of the moon, and this subject we do not pretend to advance. Enough has also been written for the benefit of those who desire an acquaintance with the intricate movements of the moon in space; and accordingly we pass this subject without notice. But very little has been written respecting the moon's physiography or the causative phenomena of the features, broad and detailed, that the surface of our satellite presents for study. Our observations had led us to some conclusions respecting the cause of volcanic energy, and the mode of its action as manifested in the characteristic craters and other eruptive phenomena that abound upon the moon's surface. We have endeavored to explain these phenomena by reference to a few natural laws, and to connect them with the general hypothesis of planet formation which is now widely accepted by cosmologists. The principal aim of our work is to lay these proffered explanations before the students and admirers of astronomy and science in general; and we trust that what we have deduced concerning the moon may be taken as referring to a certain extent to other planets."

In explanation of the illustrations, the preface furthermore sets forth that drawings were first made of the telescopic views; these were revised and repeated, many times; no favorable opportunity for observation being lost during several years. The drawings thus made were translated into models, and these properly placed in the sunlight afforded the subjects for the remarkably vivid photographs which so abundantly adorn the volume.

THE DESIGN AND CONSTRUCTION OF HARBORS: A TREATISE ON MARITIME ENGINEERING. By THOMAS STEVENSON, F. R. S. E., C. E., etc. Second Edition. Edinburgh, 1874. For sale by D. Van Nostrand. Price, $6.

It was to be expected that this standard work, first published in 1864, would reach a second edition. Mr. Stevenson has long been known and esteemed as a most reliable authority in maritime engineering. The work under notice was originally embodied in the Encyclopædia Britannica as an article on "Harbors;" and it has since been revised, both in the first and second editions of the treatise under notice; and now many aditional subjects have been introduced, while most of the chapters have been considerably extended.

The subjects treated in the several chapters are in order as follows:

I. Interior works—Exterior works—Different classes of harbors. II. Geological and other physical features. III. Generation of waves. IV. Force of the waves. V. Conditions which affect the force of waves. VI. Design of Profile, etc., of harbors in deep water. VII. Design of Profile for tidal harbors. VIII. Design of ground plan of Harbors. IX. Docks, Tide Basins, Locks, Graving Docks, Slips, etc. X. Materials, Kinds of Masonry, Implements, etc. XI. On the efficacy of tide and fresh water in preserving the outfall of Harbors and Rivers. XII. Miscellaneous subjects relating to Harbors.

ECONOMICS OF CONSTRUCTION IN RELATION TO FRAMED STRUCTURES. By ROBERT H. BOW, C. E., F. R. S. E. London, 1874. For sale by D. Van Nostrand. Price, $2.

Anyone whose connection with engineering extends some twenty years back, will remember the interest with which Mr. Bow's remarkable little book or pamphlet on bracing was received. It was the first work in English which dealt with the subject in a scientific way, and there are not a few engineers, we imagine, who are of opinion that in its way, notwithstanding the many treatises since published, it has not yet been surpassed. Why Mr. Bow did not follow up his first success with

similar works we cannot understand, but with the exception of an occasional Paper read before the Edinburgh Societies, we believe he has published nothing since 1851, and the "Economics of Construction" is therefore his second book. Mr. Bow adopts the same plan as before—that is, of crowding the utmost possible amount of information in a limited space. The subjects are roof and bridge trusses, and it seems hardly possible to imagine a truss of either kind which has not been considered. There are 200 varieties of roof trusses, and 132 varieties of framed bridges—numbers that, on first thoughts, would appear to be incredible. Some of these probably have never been as yet actually constructed, but they are none the less interesting as studies, and the whole series is a marvellous example of what can be done by the combination of triangular units. The method which Mr. Bow adopts for discovering the stresses, is the graphic method of which Professor Clerk Maxwell has been the improver, and the construction of the diagrams is shown for all the more important forms. Students who shirk studying theoretical books because they are not sufficiently grounded in mathematics to fully comprehend the reasoning, need have no difficulty here, where all that is required is a little patience and attention. As well as we can remember, there is no book in the language which so fully develops that most interesting process of finding stresses.

MANUEL DE TOXICOLOGIE. Par DRAGENDORFF. Paris: Librarie F. Savy. For sale by Van Nostrand. Price, $3.

This very complete manual has been translated from German into French by Prof. Ritter, who has also made numerous additions to the original work.

Besides the usual descriptions of salts credited with being poisonous and methods of testing for them, the authors have extended their work so far as to embrace deleterious articles of food and hurtful adulterations of most prepared foods.

The illustrations are not very abundant; indeed it is quite exceptional to find any in works of this class, unless micro-chemistry is added. There is but little reference to it in the present work. A beautiful spectrum chart is given, however, exhibiting spectra of hematin and hemoglobin.

MILK-ANALYSIS.—A Practical Treatise on the Examination of Milk and its Derivatives, Cream, Butter and Chese. By J. ALFRED WANKLYN, M. R. C. S. New York: D. Van Nostrand.

The plan of this new work on a new subject is best shown by the following extract from the preface, and the table of contents.

"In the course of this work, I have been fortunate enough to make some improvements in the art of milk-analysis, and, in particular, some little modifications in the taking of milk-residues, so as to tranfer such determinations (which before were tedious and uncertain) into the list of the simplest and most exact of chemical analyses. At the present time, when a new class of men has been constituted to watch over the food of the country, there is need for special manuals of this description."

CONTENTS. Chapter I—Introductory—Milk, its Nature and Chemical Composition—Description of each of its Constituents—Constancy of its Composition. Chapter II—Instruments and Methods for Testing Milk—Outline of Method of Milk-Analysis. Chapter III—Milk-Solids. Chapter IV—The Fat. Chapter V—Caseine. Chapter VI—Milk-Sugar. Chapter VII—Ash. Chapter VIII—Calculation and Statement of Results. Capter IX—The Milk Supply of the London Work-Houses. Chapter X—Cream. Chapter XI—Butter. Chapter XII—Cheese. Chapter XIII—Koumiss. Capter XIV—Condensed and Preserved Milk. Chapter XV—Poisonous Milk and Milk-Panics.

MISCELLANEOUS.

A PATENT has been obtained by M. Pirsch-Baudvin for a metallic alloy which is declared to resemble silver better than any other yet known with respect to color, specific gravity, malleability, ductility, sound, and other characteristics. The new alloy is a compound of copper, nickel, tin, zinc, cobalt, and iron. The following proportions are said to produce a very white metal, perfectly imitating silver: — Copper, 71.00 parts; nickel, 16.50 parts; cobalt, 1.75 parts; tin, 2.50 parts; iron, 1.25 parts; zinc, 7.00 parts. A small quantity of aluminum, about 1½ per cent., may be added. The manufacture is rather peculiar. The first step is to alloy the nickel with its own weight of the copper and the zinc in the proportion of six parts to ten of copper. The nickel alloy, the iron, the rest of the copper, the cobalt, in the form of black oxide, and charcoal are then placed all together in a plumbago crucible. This is then covered over with charcoal and exposed to great heat. When the whole is melted, the heat is allowed to subside, and the alloy of zinc and copper is added when the temperature is just sufficient to melt it. This done, the crucible is taken off the fire and its contents stirred with a hazel stick; the tin is then added, first being wrapped in paper and then dropped into the crucible. The alloy is again stirred and finally poured into the moulds; it is now ready to be rolled and wrought just like silver. A great portion of the zinc is volatilized in the act of fusion, so that a very little remains in the alloy. The superiority of this metal is said to depend principally on the cobalt, to which is due its peculiar argentine lustre.—*Engineer.*

SOLDERING IRON AND STEEL.—As it is often necessary in manufacturing operations of different kinds to unite iron and steel by other means than welding, the following practical hints, which we translate from "Wiederholds' Gewerbeblatter," will be found worth remembering:

For large and heavy pieces of iron and steel, copper or brass is used. The surfaces to be united are first filed off, in order that they may be clean. Then they are bound together with steel, and upon the joint a thin strip of sheet copper or brass is laid, or, if necessary, fastened to it with a wire. The part to be soldered is now covered with a paste of clay, free from sand, to the thickness of one inch, the coating being applied to the width of a hand on each side of the piece. It is then laid near a fire, so that the clay may dry slowly. The part to be soldered is then held be-

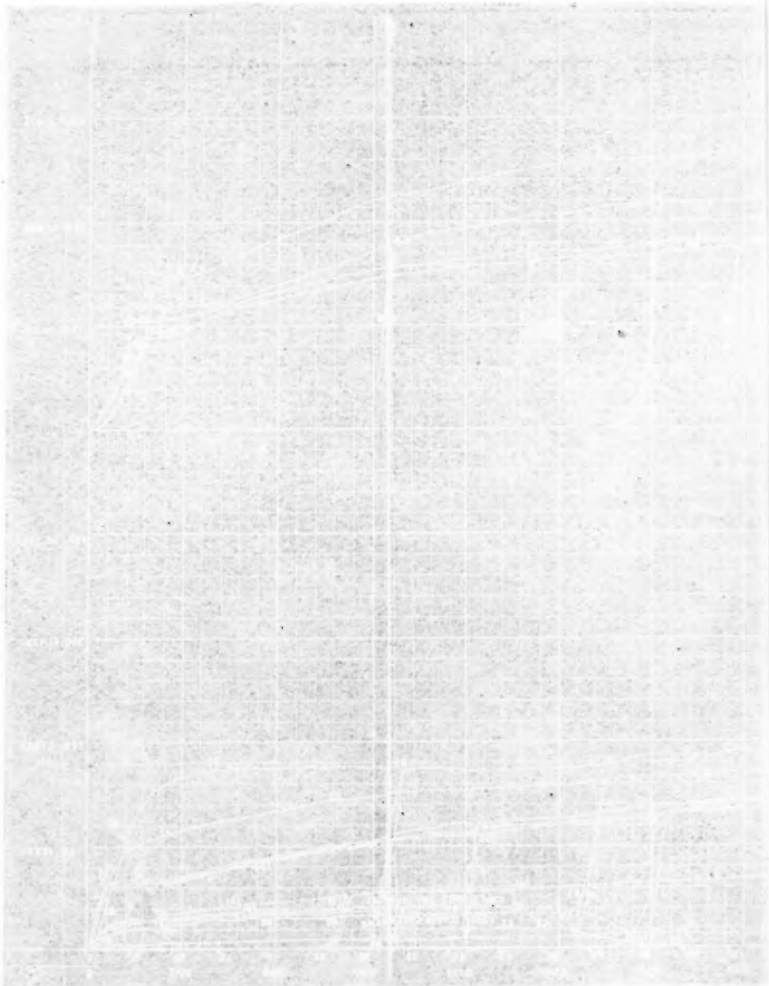
fore the blast, and heated to a white heat, whereby the clay vitrifies. If iron is soldered to iron, the piece must be cooled off in water. In soldering steel to steel, however, the piece is allowed to cool slowly. The semi-vitrified clay is then knocked off, and the surface is cleaned in a proper manner. By following the hints given, it will be found that a durable and clean soldering is obtained. If brass, instead of copper, is used, it is not necessary to heat so strongly; the former recommends itself, therefore, for steel. Articles of iron and steel of medium size are best united with hard or soft brass solder. In both cases the seams are cleanly filed and spread over with the solder and borax, when the soldering seam is heated. Hard brass solder is prepared by melting in a crucible eight parts of brass, and adding one part of previously heated zinc. The crucible is then covered and exposed to a glowing heat for a few minutes, then emptied into a pail with cold water, the water being strongly agitated with a broom. Thus the metal is obtained in small grains or granules. Soft brass solder is obtained by melting together six parts of brass, one of zinc, and one of tin. The granulation is carried out as indicated above. Small articles are best soldered with hard silver solder or soft solder. The former is obtained by alloying equal parts of fine silver and soft brass. In fusing, the mass is covered with borax, and, when cold, the metal is beaten out to a thin sheet, of which a sufficiently large and previously annealed piece is placed with borax upon the seams to be united and heated. Soft silver solder differs from hard silver solder only in that the former contains one-sixteenth of tin, which is added to it during fusion. Very fine articles of iron and steel are soldered with gold, viz., either with pure gold or hard gold solder. The latter can be obtained by fusion of one part gold, two parts silver, and three copper. Fine steel wire can also be soldered with tin, but the work is not very durable. Hard and soft brass solder are used for uniting copper and brass to iron and steel, silver solder for silver, hard gold solder for gold.—*Iron Age.*

Blue Clay for Boiler Wall.—T. B. M. writes to "Leffel's Milling and Mechanical News" as follows: Our boiler wall was first laid up with lime and sand, and would crack. We took it down next the furnace twice. The second time we could not get lime and sand, and we took the blue clay from the well which we had dug, and made a rough mortar with it, full of lumps and stones. We put plenty in, and plastered the inside well; and after two months' steady hard work, firing with cobs, and cobs and coal, even the thin inside coat is on yet, and not a crack has shown itself in the brick work, although we had steam up an hour after the bricks were laid. If this piece of experience will do anybody any good, they are welcome to it, as blue clay can always be had, while lime and sand are hard to get, and expensive, especially in this region—Central Illinois.

Chinese Rivers.—The facilities for internal commerce afforded by its large and numerous rivers and its grand canal have for ages been the pride and glory of China. But there is said to be a black sheep in every flock, and the Hoangho or the Yellow River, the second in size within the limits of the empire, is a most capricious and troublesome stream. It has repeatedly overflowed its banks, deviated widely from its former course, and wrought immense damage in populous and fertile districts. The last time this occurred was in 1853, when it left its bed about 500 miles above the Yellow Sea, and diverging north found its way into the Gulf of Pecheelee, into which it has since flowed. This change caused it to cross the grand canal, connecting Pekin with Southern China, a large section of which is washed away, and which it rendered nearly useless. These changes are caused by the large amount of sediment deposited, raising its bed until the latter becomes higher than the surrounding plain. Then in high water the river breaks through its banks and seeks the lower level. The condition of this watercourse has lately been a matter of serious consideration before the Grand Council of China, and a report has been submitted by Li Hung Chang, Viceroy of the Province in which Pekin is situated. He recommends measures to embank the river and confine it to its present course. He says that the continuity of the canal cannot be re-established, and that rather than go through with the necessary transshipment of rice, it is advisable to permanently adopt the sea route, which, in fact, has been in use for 20 years. This will compel the abandonment of junks and the use of steamships, in order to compete with foreign vessels which are constantly plying up and down the Chinese coast, and which it is now too late to exclude. To this end Li suggests that subsidies be granted to Chinese steamship companies; also that the grain taxes be commuted into a low money tax, which would obviate the necessity of much of the transportation now carried on.

Single *v.* Compound Engines.—The Committee of the Junior Naval Professional Association offer a prize of £20 for the best essay on "The Comparative Merits of Simple and Compound Engines as applied to Ships of War." The conditions of award are as follows: 1. Competition is open to all; 2. The essays must be rendered to the Honorary Secretary, care of Messrs. Griffin & Company, Portsea, before the 1st August, 1874; 3. The essays to be strictly anonymous, but each to have a motto and to be accompanied by a sealed envelope, with the motto outside and the name of the competitor inside. It is desirable that the essay should not exceed 100 pages of the size of the Proceedings of the Association; 4. The essays will be submitted for decision to Professor Cotterill, Royal Naval College, Greenwich; Chief Inspector William Eames, R. N., Chatham; and John Penn, Esq., Greenwich; 5. The essays will become the property of the Association, to publish if desirable. Communications to be sent to the Honorary Secretary, Hubert H. Grenfell, Lieut., R. N., Portsmouth.

Bombay, Baroda, and Central India Railway.—A proposal has been made for an extension of the Bombay, Baroda, and Central India Railway to Rajcote. Colonel Anderson, political agent of Kattywar, has convened a meeting of the princes and chiefs of that province upon the subject. A previous subscription made for the execution of the line produced £150,000, and at the meeting held by Colonel Anderson a further sum of £50,000 was contributed.



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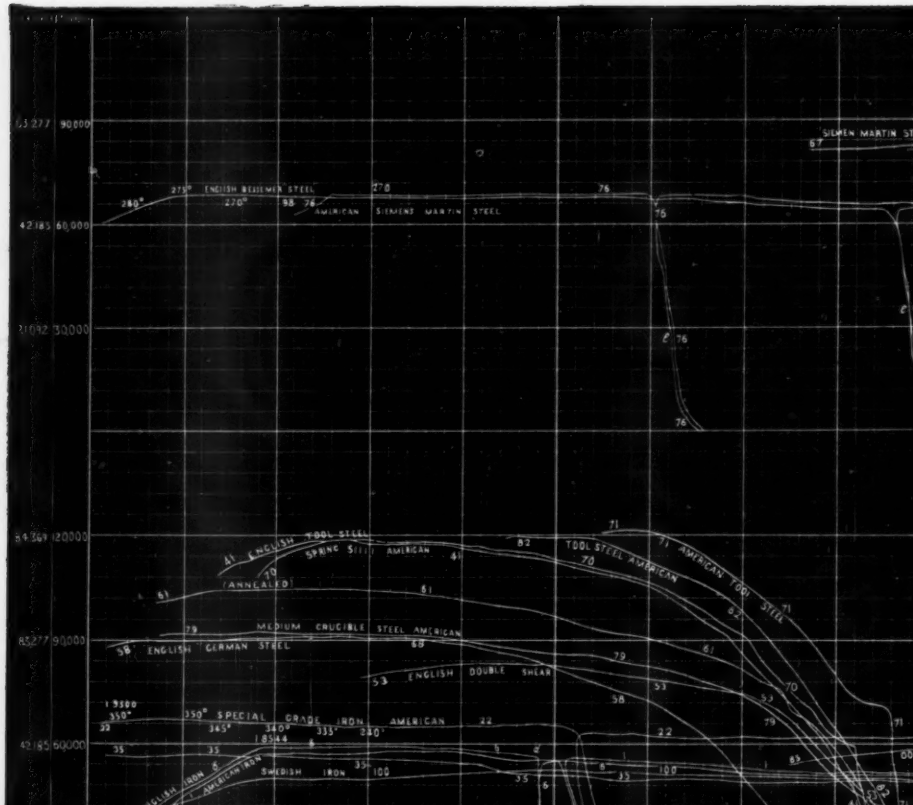
Approximate Tensile Resistance.

Kilogrammes per square Millimetre.	Pounds per square Inch of Section.



Angle of Torsion
Elongation.

PLATE II.

TOGRAPHIC STRAIN-DIAGRAMS OF MET

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TESTING MACHINE OF PROFESSOR R. H. THURSTON.

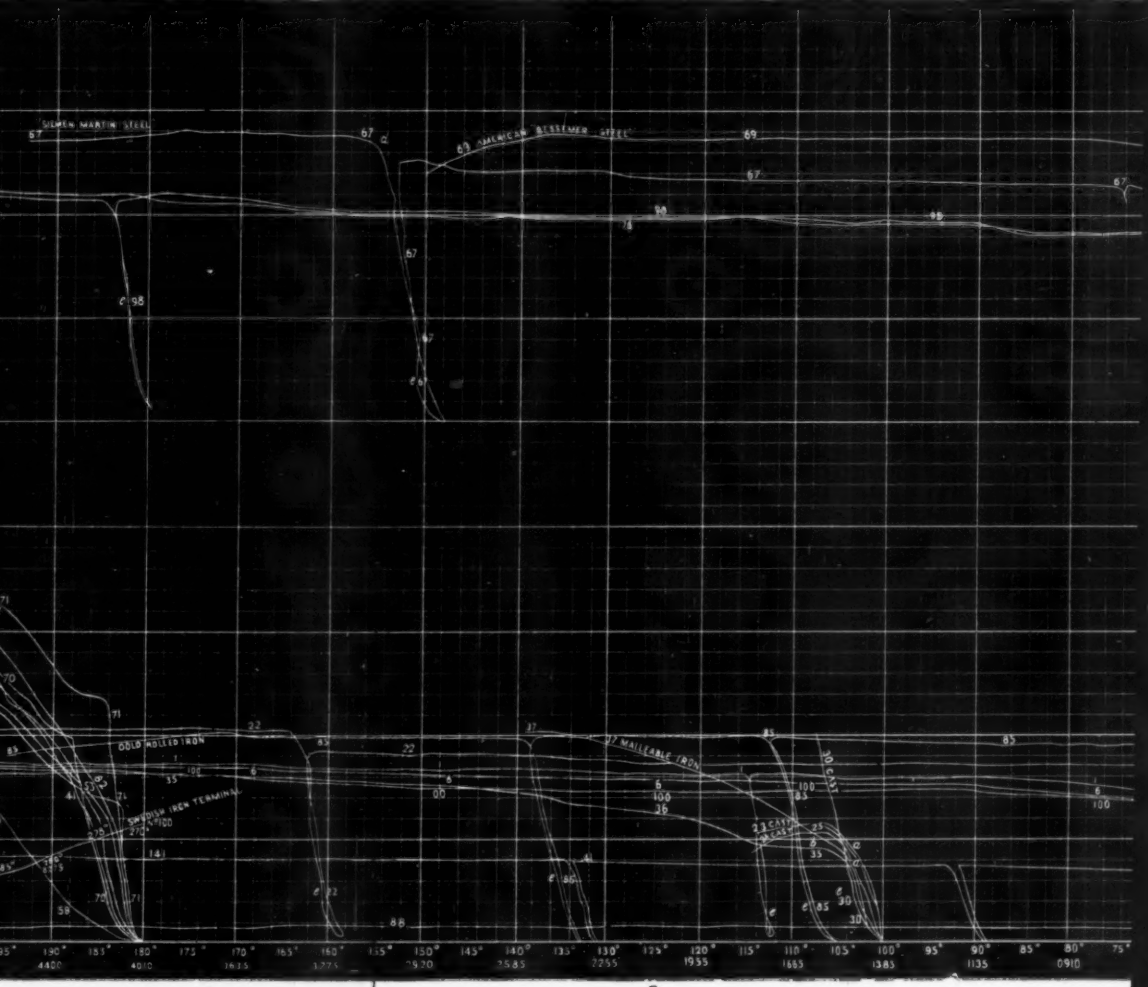

PLATE II.

TRAIN-DIAGRAMS OF METALS

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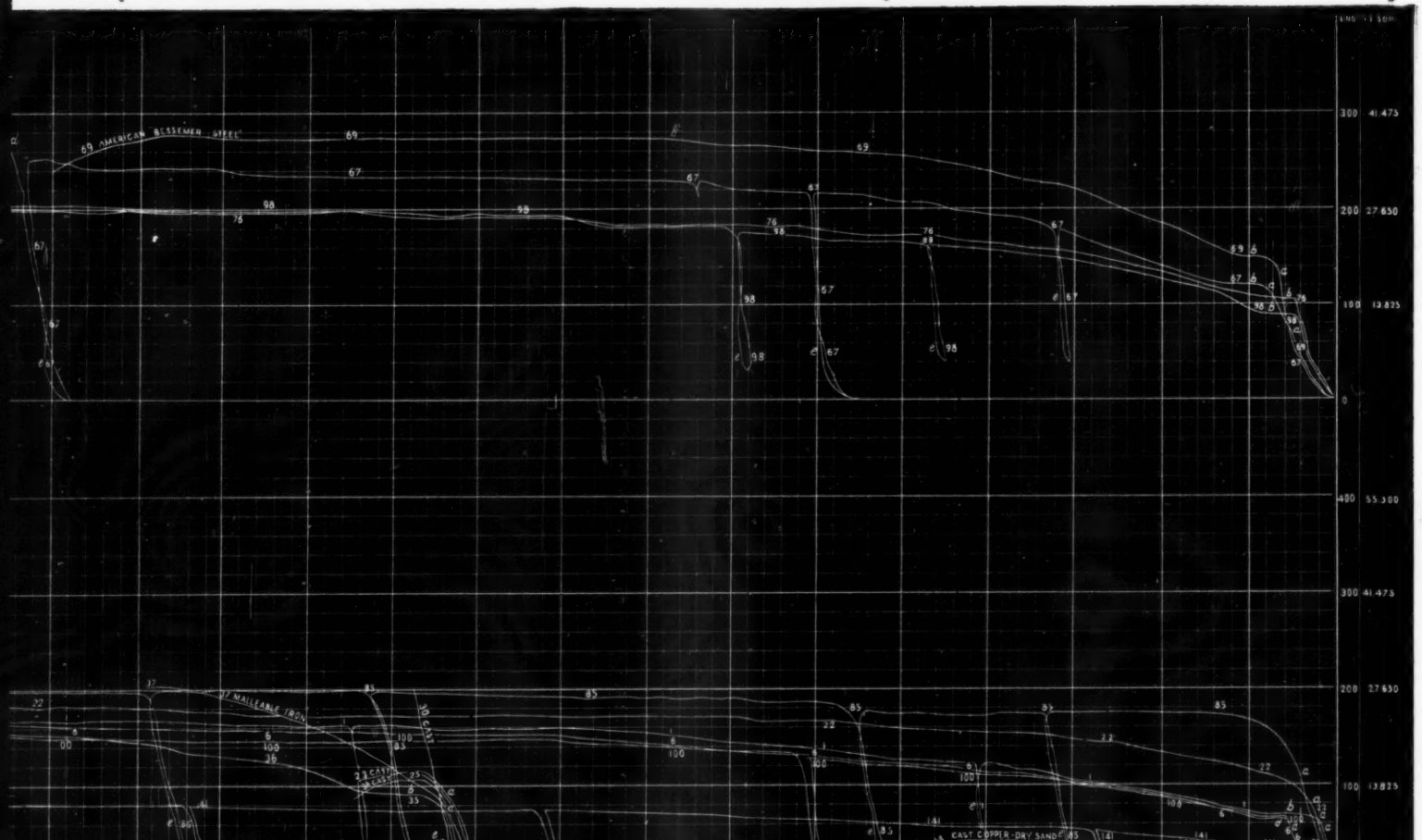
HINE OF PROFESSOR R. H. THURSTON.